Bapuji Educational Association ®
Bapuji Institute of Engineering and Technology, Davangere – 577 004
Department of Civil Engineering

Course File Check List

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Revised-Academic Calendar of EVEN semesters of UG Programmes for 2020-2021

Semesters EVENTS	IV semester B.E./B.Tech.	IV semester B.Arch./ B.Plan.	VI semester B.E./B.Tech.	VI semester B.Plan./B.Arch	VIII semester B.E./B.Tech.	VIII semester B.Plan.	VIII semester B.Arch
Commencement of EVEN Semester	19.04.2021	19.04.2021	19.04.2021	19.04.2021	19.04.2021	19.04.2021	19.04.2021
Last Working day of EVEN Semester	07.08.2021	07.08.2021	07.08.2021	07.08.2021	#20.07.2021	#20.07.2021	07.08.2021
Practical Examinations	09.08.2021 To 19.08.2021	09.08.2021 To 19.08.2021	09.08.2021 To 19.08.2021	—	—	—	—
Theory Examinations	23.08.2021 To 09.09.2021	23.08.2021 To 09.09.2021	23.08.2021 To 09.09.2021	10.08.2021 To 31.08.2021	22.07.2021 To 30.07.2021	22.07.2021 To 30.07.2021	10.08.2021 To 17.08.2021
Internship	—	—	—	—	—	—	—
Internship Viva-Voce/ Project Viva-Voce	—	—	—	—	02.08.2021 To 06.08.2021	—	—
Professional training / Organization study	—	—	—	—	—	—	—
Commencement of ODD Semester	13.09.2021	13.09.2021	13.09.2021	13.09.2021	—	—	23.08.2021

- The classroom sessions for even the semester should commence from the dates mentioned above.
- The Institute needs to function for **six days** a week with additional hours (**Saturday is a full working day**). #if required the college can plan to have extra classes even on Sundays also.
- If any of the above dates are declared to be a holiday then the corresponding event will come into effect on the next working day.
- Notification regarding the Calendar of Events relating to the conduct of **University Examinations** will be issued by the Registrar (Evaluation) from time to time.
- The faculty/staff shall be available to undertake any work assigned by the university.
- Academic Calendar may be modified based on guidelines/directions issued in the future by MHRD/UGC/AICTE/State Government.
- Revised Academic Calendar is also applicable for **Autonomous Colleges.** In case if any changes are to be affected by Autonomous Colleges in the academic terms and examination schedule, they could do so with the approval of the University.

21.04.2021

REGISTRAR

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Bapuji Institute of Engineering and Technology, Davanagere

CALENDER OF EVENTS-EVEN SEMESTER: APRIL 2021-SEP 2021 (Tentative)

PARTICULARS	IV sem BE/B.Tech	VI sem BE/B.Tech	VIII sem BE/B.Tech
Commencement of even sem	19-04-2021	19-04-2021	19-04-2021
Last Working Day	07-08-2021	07-08-2021	20-07-2021
1st IA Test Series	31-05-2021 To 05-06-2021	31-05-2021 To 05-06-2021	24-05-2021 To 29-05-2021
2nd IA Test Series	01-07-2021 To 07-07-2021	01-07-2021 To 07-07-2021	21-06-2021 To 26-06-2021
3rd IA Test Series	31-07-2021 To 06-08-2021	31-07-2021 To 06-08-2021	13-07-2021 To 19-07-2021
Practical Examination	09-08-2021 To 19-08-2021	09-08-2021 To 19-08-2021	—
Theory Examination	23-08-2021 To 09-09-2021	23-08-2021 To 09-09-2021	22-07-2021 To 30-07-2021
Internship Viva-Voce	—	—	02-08-2021 To 06-08-2021
Commencement of odd semester	13-09-2021	13-09-2021	—

Forum activities:

Dept. of Chemical Engg.	Dept. of E& C	Dept. of EEE	Dept. of Mech. Engg.
Interdepartmental Sports 25-05-2021 Anthyakshari 29-05-2021 CHEMEXCEL-2021 04-06-2021 Industrial Visit 05-06-2021 Guest Lecture 28-06-2021	NB Cup Cricket tournament inauguration 24-5-2021 E-Utsav 2021, Papyrus 2,3 June 2021	Online Impulse 26-5-2021 5 Day online Webinar on Operational Planning in Power System 10-14 May 2021	Mech-I-Prix State Level Paper Presentation Competition 25-05-2021

Principal

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Vision of BIET

To be a center of excellence recognized nationally and internationally, in distinctive areas of engineering education and research, based on a culture of innovation and invention.

Mission of BIET

BIET contributes to the growth and development of its students by imparting a broad based engineering education and empowering them to be successful in their chosen field by inculcating in them positive approach, leadership qualities and ethical values

VISION OF THE DEPARTMENT

To train the students to become Civil Engineers with leadership qualities, having ability to take up professional assignments and research with a focus on innovative approaches to cater to the needs of the society.

MISSION OF THE DEPARTMENT

1. To provide quality education through updated curriculum and conducive teaching learning environment for the students to excel in higher studies, competitive examinations and professional career.
2. To impart soft skills, leadership qualities and professional ethics among the graduates to handle the projects independently with confidence.
3. To deal with the contemporary issues and to cater to the socio-economic needs.
4. To build industry-institute interaction and to establish good rapport with alumni.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: Core Competence: Graduates will be able to plan, analyse, design and construct sustainable Civil Engineering Infrastructure.

PEO 2: Professional Skills: Graduates will be professional engineers with a sense of ethics, creativity, leadership, self-confidence and independent thinking to cater to the needs of the society.

PEO 3: Societal Needs: Graduates will be able to contribute effectively for the development of industry and professional bodies.

PEO 4: Cognitive Intelligence: Graduates will be able to take up competitive examinations, higher studies and involve in research and entrepreneurship activities.

PROGRAM SPECIFIC OUTCOMES (PSOs)

Students after the completion of the Program will be able to

1. Apply the fundamental concepts, software and codal provisions in the analysis, design and construction of sustainable civil engineering infrastructure.
2. Inculcate professional and leadership qualities, sense of ethics and confidence related to civil engineering.

Faculty will be able to

3. Contribute to the overall development of civil engineering community through the professional bodies and offer services to the society.

65	Leveling Staff	08-01-2014	10	12,000.00	Guruji Instruments Hubli, Karnataka
66	Cross Staff	08-01-2014	4	2,600.00	Guruji Instruments Hubli, Karnataka
67	Open cross Staff	08-01-2014	2	1300.00	Guruji Instruments Hubli, Karnataka
68	Round Optical square	08-01-2014	6	5,100.00	Guruji Instruments Hubli, Karnataka
69	Plane table with access	08-01-2014	4	28,000.00	Guruji Instruments Hubli, Karnataka
70	Tape 30 mtr fiber Glass	08-01-2014	20	8,500.00	Guruji Instruments Hubli, Karnataka
71	Arrows	08-01-2014	150	5,700.00	Guruji Instruments Hubli, Karnataka
72	Leveling Staff	28-12-2014	8	9,600.00	Guruji Instruments Hubli, Karnataka
73	Trough Compass	28/12/2014	8	3,200.00	Guruji Instruments Hubli, Karnataka
74	Metallic Tape	28-12-2014	8	3,400.00	Guruji Instruments Hubli, Karnataka
75	Battery for Total Station	03-03-2017	1	13,168.00	Guruji Instruments Hubli, Karnataka
11	Vernier Thedolite	23/01/2018	8	158400	Guruji Instruments Hubli, Karnataka
	Prismatic		12	22200	
	Compass		1	1850	
	Leveling Staff		6	7500	
	Metallic Tape 30M		6	3180	
			Total	216500.00	
76	Prismatic Compass	11/02/2019	10	22000	Guruji Instruments Hubli, Karnataka
	Wooden Cross Staff		10	9750	
	Arrows		300	21000	
			Total	52750	
		Total		62245	
77	Pentax Total Station with all accessories	04/03/2021	02	762711.86	Lawrence & Mayo(I) Pvt. Ltd. #179-G 96 5/1, Narasimha Road, Bangalore-56002
		Total		900000.00	

Name of the Faculty: Kum. Supriya Xavier Lopes

Time / Day	8 – 9	9 – 10	10.30 – 11.30	11.30 – 12.30	2 – 3	3 – 4	4 – 5
Mon		18CV43 – A		20CSE22 – SDA			
Tue				18CV43 – A			
Wed	18CV43 – A			20CSE22			
Thu			20CSE22		15/17CVL67 – (RSC+SXL)		
Fri	20CSE22				18CVL48 – A3 (ARC+SXL)		
Sat		20CSE22 – SDA					

1.
2.
Time Table Coordinator

HOD

Principal

TITLE OF THE COURSE: **APPLIED HYDRAULICS**
IV Semester
[As per Choice Based Credit System (CBCS) scheme]

Course Code	**18CV43**	**CIE Marks**	**40**
Number of Lecture	**03**	**SEE Marks**	**60**
Total Number of Lecture Hours	**40 (08 Hours per Module)**	**Exam Hours**	**03**

Credits – 03

Course Objectives: The objectives of this course is to make students to learn:

1. Principles of dimensional analysis to design hydraulic models and Design of various models.
2. Design the open channels of various cross sections including design of economical sections.
3. Energy concepts of fluid in open channel, Energy dissipation, Water surface profiles at different conditions.
4. The working principles of the hydraulic machines for the given data and analyzing the performance of Turbines for various design data.

Module-1

Dimensional analysis: Dimensional analysis and similitude: Dimensional homogeneity, Non Dimensional parameter, Rayleigh methods and Buckingham ð theorem, dimensional analysis, choice of variables, examples on various applications.

Model analysis: Model analysis, similitude, types of similarities, force ratios, similarity laws, model classification, Reynolds model, Froude's model, Euler's Model, Webber's model, Mach model, scale effects, Distorted models. Numerical problems on Reynold's, and Froude's Model

Buoyancy and Flotation: Buoyancy, Force and Centre of Buoyancy, Metacentre and Metacentric height, Stability of submerged and floating bodies, Determination of Metacentric height, Experimental and theoretical method, Numerical problems

L1, L2, L3, L4

Open Channel Flow Hydraulics:

Uniform Flow: Introduction, Classification of flow through channels, Chezy's and Manning's equation for flow through open channel, Most economical channel sections, Uniform flow through Open channels, Numerical Problems. Specific Energy and Specific energy curve, Critical flow and corresponding critical parameters, Metering flumes, Numerical Problems

L3,L4

Non-Uniform Flow: Hydraulic Jump, Expressions for conjugate depths and Energy loss, Numerical Problems Gradually varied flow, Equation, Back water curve and afflux, Description of water curves or profiles, Mild, steep, critical, horizontal and adverse slope profiles, Numerical problems, Control sections

L2,L3,L4

Module-4

Hydraulic Machines:

Introduction, Impulse-Momentum equation. Direct impact of ajet on a stationary and moving curved vanes, Introduction to concept of velocity triangles, impact of jet on a series of curved vanes- Problems

Module-4

Arches and Cable Structures: Three hinged parabolic arches with supports at the same and different levels. Determination of normal thrust, radial shear and bending moment. Analysis of cables under point loads and UDL. Length of cables for supports at same and at different levels- Stiffening trusses for suspension

Module-5

Influence Lines and Moving Loads: Concepts of influence lines-ILD for reactions, SF and BM for determinate beams-ILD for axial forces in determinate trusses-Reactions, BM and SF in determinate beams using rolling loads concepts.

L2, L4, L6

Course outcomes: After studying this course, students will be able to:

1. Evaluate the forces in determinate trusses by method of joints and sections.
2. Evaluate the deflection of cantilever, simply supported and overhanging beams by different methods
3. Understand the energy principles and energy theorems and its applications to determine the deflections of trusses and bent frames.
4. Determine the stress resultants in arches and cables.
5. Understand the concept of influence lines and construct the ILD diagram for

Text Books:

1. Reddy C S, Basic Structural Analysis, Tata McGraw Hill, New Delhi.
2. Muthu K U. etal, Basic Structural Analysis, 2nd edition, IK International Pvt. Ltd., New Delhi,2015.
3. Bhavikatti, Structual Analysis, Vikas Publishing House Pvt. Ltd, New Delhi, 2002.

Reference Books:

1. Hibbeler R C, Structural Analysis, Prentice Hall, 9th edition, 2014
2. Devadoss Menon, Structural Analysis, Narosa Publishing House, New Delhi, 2008.

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI
Scheme of Teaching and Examination 2018 – 19
Outcome Based Education(OBE) and Choice Based Credit System (CBCS)
(Effective from the academic year 2018 – 19)

Programme: CIVIL ENGINEERING

IV SEMESTER

Sl. No	Course and Course code		Course Title	Teaching Department	Teaching Hours /Week			Examination				Credits
					Theory Lecture	Tutorial	Practical/ Drawing	Duration in hours	CIE Marks	SEE Marks	Total Marks	
					L	T	P					
1	BSC	18MAT41	Mathematics(Title as per the decision of BoS in Sciences)	Mathematics	2	2	--	03	40	60	100	3
2	PCC	18CV42	Analysis of Determinate Structures		3	2	--	03	40	60	100	4
3	PCC	18CV43	Applied Hydraulics		3	0	--	03	40	60	100	3
4	PCC	18CV44	Concrete Technology		3	0	--	03	40	60	100	3
5	PCC	18CV45	Advanced Surveying		3	0	--	03	40	60	100	3
6	PCC	18CV46	Water Supply & Treatment Engineering		3	0	--	03	40	60	100	3
7	PCC	18CVL47	Engineering Geology Laboratory		--	2	2	03	40	60	100	2
8	PCC	18CVL48	Fluid Mechanics and Hydraulics Machines Laboratory		--	2	2	03	40	60	100	2
9	HSMC	18KVK39/49	Vyavaharika Kannada (Kannada for Communication)/	HSMC	--	2	--	--	100	--	100	1
		OR										
		18KAK39/49	Aadalitha Kannada (Kannada for Administration)									
		OR										
		18CPC39/49	Constitution of India, Professional Ethics and Cyber Law		1	--	--	03	40	60		
					Examination is by objective type questions							
				TOTAL	**17** **OR** **18**	**10** **OR** **08**	**04**	**24** **OR** **27**	**420** **OR** **360**	**480** **OR** **540**	**900**	**24**

Note: BSC: Basic Science Course, PCC: Professional Core Course, HSMC: Humanity and Social Science Course, NCMC: Non-Credit Mandatory Course.

18KVK39, Vyavaharika Kannada (Kannada for Communication) is offered for the students of Non-Kannada Speaking, Reading and Writing

18KAK39 Aadalitha Kannada (Kannada for Administration) is offered for the students who speak, read and write in Kannada.

Course prescribed to lateral entry Diploma holders admitted to III semester of Engineering programs

10	NCMC	18MATDIP41	Additional Mathematics - II	Mathematics	02	01	--	03	40	60	100	0

(a)The mandatory non – credit courses such as Additional Mathematics I and II prescribed for III and IV semesters respectively, Introduced to the lateral entry Diploma holders admitted to III semester of BE/B.Tech programs, they shall attend the classes during the respective semesters to complete all the formalities of the courses and appear for the University Examination. In case of any student fails to register for the said course/fails to secure the minimum 40 % of the prescribed CIE marks, the candidates shall be awarded F grade. In such a case, the students have to fulfill the CIE requirements during subsequent semester/s to appear for SEE.

(b)These Courses shall not be considered for vertical progression, however completion of the courses shall be mandatory for the award of degree.

Courses prescribed to lateral entry B.Sc degree holders admitted to III semester of Engineering programs

Lateral entrant students from B.Sc. Stream, shall clear the non-credit courses Engineering Graphics and Elements of Civil Engineering and Mechanics of the First Year Engineering Programme. These Courses shall not be considered for vertical progression; however completion of the courses shall be mandatory for the award of degree.

AICTE Activity Points to be earned by students admitted to B E / B Tech / B Plan day college programme (For more details refer to Chapter 6,AICTE Activity Point Programme, Model Internship Guidelines):

Over and above the academic grades, every regular student (Day Scholar) admitted to the 4 years Degree programme and every student entering 4 years Degree programme through lateral entry, shall earn 100 and 75 Activity Points respectively, for the award of degree through AICTE Activity Point Programme. Students migrated from other Universities to fifth semester are required to earn 50 Activity Points from the year of entry to VTU. The respective Activity Points earned by the students shall be reflected in the eighth semester Grade Card.

The earning of activities by the students can be spread evenly over the years, students are at a liberty to choose the kind of activities and to complete the them anytime during the semester weekends and holidays which will enhance their personality index, without affecting the academic work load of the semester, However, minimum hours' requirement should be fulfilled. Activity Points (non-credit) have no effect on SGPA/CGPA and shall not be considered for vertical progression.

In case students fail to earn the prescribed activity Points within the stipulated period, Eighth semester Grade Card shall be issued only after earning the required activity Points such students shall not be admitted for the award of degree.

Title & Code	**Applied Hydraulics (18CV43)**
CO	**Statement**
18CV43.1	**Apply** the dimensional analysis concept for developing mathematical modelling and **compute** the parametric values in prototype by analysing the corresponding model parameters
18CV43.2	**Explain** the concepts of buoyancy and flotation
18CV43.3	**Design** the cross section of channels with uniform flow.
18CV43.4	**Apply** energy concepts in non-uniform flow
18CV43.5	**Apply** the concepts of impulse momentum equation to verify the performance characteristics of turbines
18CV43.6	**Evaluate** the performance characteristics of centrifugal pumps.

Course Title		**Applied Hydraulics**									
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
18CV43.1	2	2		1								2
18CV43.2	2	2		1								2
18CV43.3	2	2	2	1								2
18CV43.4	2	2		1								2
18CV43.5	2	2	2	1								2
18CV43.6	2	2	2	1								2
Average	2	2	2	1								2

CO	**PSO1**	**PSO2**
18CV43.1	2	2
18CV43.2	2	2
18CV43.3	2	2
18CV43.4	2	2
18CV43.5	2	2
18CV43.6	2	2
Average	2	2

Subject : Applied Hydraulics Subject Code : 18CV43 Class : 4th 'A'

Period	Date	Topics Planned	Date	Topics Covered	Remarks
1	26/4/21	Module-1 : Dimensional analysis & similitude Dimensional homogeneity	26/4/21	Module-1 : Dimensional Analysis & Similitude	
2	27/4/21	Non dimensional parameters Rayleigh methods and Buckingham π Theorem	27/4/21	Dimensional homogen-iety	
3	28/4/21	Dimensional analysis choice of variables, examples.	28/4/21	Non dimensional parameters	
4	3/5/21	Model analysis, similitude, types force ratios	3/5/21	Rayleigh methods and Buckingham π Theorem	
5	4/5/21	Similarity laws model classification	4/5/21	Dimensional Analysis Choice of variables examples	
6	5/5/21	Reynolds model Froude's model Eulers, webbers	5/5/21	Model analysis, similitude, types of force ratios	
7	10/5/21	scale effects, distorted models, Numerical Problems	10/5/21	Similarity laws Model Classification	
8		Buoyancy, Force and centre of Buoyancy Metacentre	11/5/21	Reynolds Model Froude's, Eulers, Webbers model	
9		Meta centric stability of submerged & floating bodies.	12/5/21	scale effects, distorted models, Numerical Problems	
10		Determination of Meta centric height, Exp. & theoretical method	17/5/21	Buoyancy, Force and centre of Buoyancy Metacentre	
11		Module-2 : Uniform flow, classification of flow	18/5/21	Meta centric stability of submerged and floating bodies.	
12		Chezy's & Mannings eqn for flow through open channel.	19/5/21	Determination of Meta centric height, Exp & theoretical Mtd.	
13		Most economical channel sections	24/5/21	Module-2 : Uniform flow, classification of flow.	
14		Numerical Problems	26/5/21	Chezy's & Mannings eqn for flow through open channel.	
15		Uniform flow through open channels.	27/5/21	Most economical Channel sections	
16		Specific energy and specific energy curve	31/5/21	Numerical Problems	
17		Numerical	.12'	Uniform flow through	

LESSON PLAN

Subject : Applied Hydraulics Subject Code : 18CV43 Class : 4th A

Period	Date	Topics Planned	Date	Topics Covered	Remarks
18		Critical flow and corresponding critical parameters	2/6/21	Specific energy and sp. energy curve	
19		Module-3 : Hydraulic jump, expression for conjugate depths	14/6/21	Numerical problems	
20		Energy loss, Numerical problems, Gradually varied flow	15/6/21	Critical flow and corresponding critical parameters	
21		Back water curve & afflux, description of H_2O curves or profiles	16/6/21	Module-3, Hydraulic jump expr for conjugate depths	
22		Mild, steep, critical, hztl and adverse slope profiles	21/6/21	Energy loss, Numerical problems, Gradually varied flow.	
23		Numerical problems	22/6/21	Back water curve and afflux, description of H_2O curves or profiles	
24		Numerical problems	23/6/21	Mild, steep, critical hztl & adverse slope profiles	
25		Numerical problems.	28/6/21	Numerical problems	
26		Numerical problems.	29/6/21	Numerical problems	
27		Module-4 : Introduction to impact of jet on Vanes	29/6/21	Numerical problem	
28		Impulse-Momentum eqn Direct impact of jet on stationary	30/6/21	Numerical problems	
29		Moving curved Vanes	13/7/21	Module 4 : Introduction to impact of jet on Vanes	
30		Introduction to velocity triangles	14/7/21	Impulse-Momentum eqn Direct impact of jet on stationary	
31		Impact of jet on a series of curved vanes	16/7/21	Moving curved Vanes	
32		Introduction to turbines, heads and efficiencies	19/7/21	Introduction to velocity Δs	
33		Classification of turbines	26/7/21	Impact of jet on a series of curved vanes	
		Pelton wheel		Introduction to	

LESSON PLAN

Subject : Applied Hydraulics Subject Code : 18CV43 Class : 4th 'A'

Period	Date	Topics Planned	Date	Topics Covered	Remarks
35		Module 5: Radial flow reaction turbines	28/7/21	Classification of turbines	
36		Francis turbine Working principle	2/8/21	Pelton Wheel working principle	
37		Kaplan turbine working principle	3/8/21	Module 5 : Radial flow reaction turbines	
38		Draft tube centrifugal pumps types of C.P.	4/8/21	Francis Turbine Working principle	
39		Workdone by the impeller	9/8/21	Kaplan turbine	
40		Heads & efficiencies min starting speed of centrifugal pump.	10/8/21	Draft tube. Centrifugal pumps	
			16/8/21	Workdone by the Impeller	
			17/8/21	Heads & efficiencies min starting speed of C-P.	
			~~17/8/21~~		

LESSON PLAN

Period	Date	Topics Planned	Date	Topics Covered	Remarks

Text Books :

1. P.N. Modi & S.M. Seth, "Hydraulics & Fluid Mechanics including Hydraulic Machines" 20th edition 2015.
2. R.K. Bansal, "A text book of fluid Mechanics & hydraulic Machines", Laxmi Publications, New Delhi.

Reference Books :

1. K. Subramanya – 'FM and HM'
2. Mohd. Kaleem Khan – FM and machinery
3. CSP Ojha, R. Berndtsson & P.N. Chandramouli
4. J. B. Evett & C. Liu, "FM & Hydraulics"
5. ....

Date	Topics Discussed	Remarks

Test	Date	Class Strength	No. of Students Appeared	No. of Students Scored < 15	Signature of the HOD
T1	8/6/2021	69	69	—	
T2	6/7/2021	69	69	—	
T3	3/8/2021	69	69	—	

LESSON PLAN

Subject :

Subject Code :

Class :

Period	Date	Topics Planned	Date	Topics Covered	Remarks

Class : IV - A

Subject Code : 18CV43

Subject : Applied Hydraulics

Total No. of Classes : 42

Sl No.	USN	NAME	DATE																												No. of Days Present	%	Test Marks			Average	Remarks
	4BD		26/4/21	27/4/21	28/4/21	3/5/21	4/5/21	5/5/21	10/5/21	11/5/21	12/5/21	17/5/21	18/5/21	19/5/21	25/5/21	26/5/21	27/5/21	31/5/21	1/6/21	2/6/21	4/6/21	15/6/21	16/6/21	21/6/21	22/6/21	23/6/21	28/6/21	29/6/21	29/6/21	30/6/21			I	II	III		
1	17CV052	Mohammed Azhar Basith	1	2	3	4	5	6	7	8	9	10	11	12	13	A	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	24	25	25	25	10	35
2	18CV027	Harshith N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	24	27	10	37
3	76	Shivaraj K H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	11	23	10	33
4	99	Vinay Kumar M	1	2	3	4	5	6	7	8	9	10	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	14	24	10	34
5	19CV001	Aban Sharief	A	2	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	25	27	10	37
6	003	Afzal Noorsabnavar	A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	14	24	10	34
7	05	Akashdeep R Andanur	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	27	28	23	26	10	36
8	06	Akhila C Akula	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	30	28	28	29	10	39
9	07	Akshata Ashoka Putalekara	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	30	30	30	10	40
10	09	Akshaya Kumara L M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	A	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	28	24	27	10	37
11	11	Amith K M	1	2	3	4	5	6	7	8	A	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	14	24	10	34
12	13	Arpitha Basanagouda Patil	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	A	16	17	18	19	20	21	22	23	24	25	26	27	95	27	28	22	26	10	36
13	15	Basavaraj S Patil	1	2	3	4	5	6	7	8	9	10	11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95						
14	17	Bhumika P	1	2	3	4	5	6	7	8	9	10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	28	15	24	16	34
15	19	Chinmayee K	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	A	21	22	23	24	25	26	27	93	29	28	26	28	10	38
16	21	Darshan V N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	A	20	21	22	23	24	25	26	27	95	28	28	13	23	10	33
17	23	Ganesh U Shirigeri	1	2	3	4	5	6	7	8	9	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	25	26	27	95	28	28	20	26	10	36
18	25	Hemanth Kumar DV	1	2	3	4	A	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	28	14	24	10	34
19	29	Kruthik S P	1	2	3	4	5	6	A	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	28	20	26	10	36
20	33	Manjunatha M	1	2	3	4	5	6	7	8	9	A	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	93	28	29	27	28	10	38
21	35	Mithun Y	1	2	3	4	5	6	7	8	9	10	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	93	28	28	17	25	10	35
22	37	Mohammed Faizan Makandar	1	2	3	4	5	6	7	8	9	10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	28	11	23	10	33
23	39	Nadeem Sha AZ	1	2	3	4	5	6	7	8	9	10	11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	22	28	23	25		35
24	41	Nanda K B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	A	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	15	24	10	34
25	43	Niranjan G M	1	2	3	4	5	6	7	8	9	10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	28	15	24	10	34
26	47	Pooja P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	A	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	28	10	22	10	32
27	49	Pradeep PN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	A	19	20	21	22	23	24	25	26	27	95	28	28	18	25	10	35
28	51	Prashanth N R	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	A	23	24	25	26	27	98	27	28	19	25	10	35
29	53	Raghavendra Vadithe	1	2	3	4	5	6	A	A	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	95	28	28	13	23	10	33
30	55	Rakesh H N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	A	98	28	28	14	24	10	34
		Initials of Teacher																																			
		Initials of H.O.D.																																			

Class : IV - A Subject Code : 18CV43 Subject : Applied Hydraulics Total No. of Classes : 42

Sl No.	USN 4BD	NAME DATE	26/4/21	27/4/21	28/4/21	3/5/21	4/5/21	5/5/21	10/5/21	11/5/21	12/5/21	17/5/21	18/5/21	19/5/21	25/5/21	26/5/21	28/5/21	31/5/21	1/6/21	2/6/21	14/6/21	15/6/21	16/6/21	21/6/21	22/6/21	23/6/21	28/6/21	29/6/21	29/6/21	30/6/21	No. of Days Present	%	Test Marks			Average	Remarks
																																	I	II	III		
31	19CV057	Sambhram S Patil	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	29	4	21	10	31
32	59	Sevanth B M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	27	28	19	25	10	35
33	61	Shreya D K	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	28	15	24	10	34
34	63	Soundarya N M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	A	17	18	19	20	21	22	23	24	25	26	27	98	28	28	16	24	10	34
35	65	Swathi V Kote	1	2	3	4	5	6	7	8	9	10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	9	22	10	32
36	67	U Madhushree	1	2	3	4	5	6	7	8	9	10	11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95	28	30	28	29	10	39
37	71	Veeresh K K	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	28	20	26	10	36
38	73	Vijayalakshmi R Telkar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	27	28	22	26	10	36
39	75	Vikas S M	A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	95	27	28	21	26	10	36
40	77	Vivekananda H M	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	28	20	26	10	36
41	79	Yugh B Jain	1	2	3	4	5	6	7	8	9	10	A	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	11	23	10	33
42	81	Kiran M M	1	2	3	4	5	6	7	8	9	10	11	A	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	27	28	23	26	10	36
43	82	Santhosh S Bagoor	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	A	18	19	20	21	22	23	24	25	26	27	98	28	28	25	27	10	37
44	20CV400	Abhilash S V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	A	98	28	28	14	24	10	34
45	402	Ambika H J	1	2	3	4	5	6	7	8	9	10	11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	27	28	23	26	10	36
46	404	Bharath Reddy N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	24	27	10	37
47	406	Channesh H Patel	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	16	24	10	34
48	407	Chetan Koteraiah	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	28	15	24	10	34
49	411	Deepak L	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	30	30	30	10	40
50	412	Dhanush R	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	24	27	10	37
51	413	Firdosh Anjum H	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	27	28	19	25	10	35
52	416	Harish L G	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	28	25	27	10	37
53	417	Harish S D	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	24	27	10	37
54	418	Harsha C N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	28	25	27	10	37
55	423	Mohammed Khadir	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	25	27	10	37
56	428	Murugarajendra H V	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	25	27	10	37
57	429	Nandish G Mathad	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	30	28	28	29	10	39
58	430	Pallavi O	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	29	28	26	28	10	38
59	431	Rohith A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	25	27	10	37
60	433	Sandeep B N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	28	28	17	25	10	35
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Class : IV-A Subject Code : 18CV43 Subject : Applied Hydraulics Total No. of Classes : 42

Sl No.	USN 4BD	NAME DATE	26/4/21	27/4/21	28/4/21	3/5/21	4/5/21	5/5/21	10/5/21	11/5/21	12/5/21	17/5/21	18/5/21	19/5/21	24/5/21	26/5/21	27/5/21	31/5/21	1/6/21	2/6/21	14/6/21	15/6/21	16/6/21	21/6/21	22/6/21	23/6/21	28/6/31	29/6/31	29/6/31	30/6/21	No. of Days Present	%	Test Marks			Average	Remarks
																																	I	II	III		
61	20CV 435	Shankar Rao Kulkarni C	1	2	3	4	5	6	7	8	9	10	11	12	13	A	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	10	22	10	32
62	437	Shree Harsha JR	1	2	3	4	5	6	7	8	9	10	11	12	A	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	28	28	17	25	10	35
63	439	Surabhi S Bharadwaj	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	27	28	19	25	10	35
64	440	Suraj N Raikar	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	29	28	27	28	10	38
65	441	Thriveni G	1	2	3	4	5	6	7	8	9	10	11	12	13	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	98	27	28	21	26	10	36
66	442	Trupti S Balikai	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	30	28	29	10	39
67	443	Trupti Sadanand Ramagiri	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	100	28	28	24	27	10	37
68	444	Veena B Bharamagoudra	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	98	29	28	27	28	10	38
69	448	Vinodkumar Budihal	1	2	A	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	93	28	28	08	[illegible]	10	32
		Initials of Teacher																																			
		Initials of H.O.D.																																			

Dimensional Analysis

Dimensional Analysis is a mathematical technique to solve any engineering problem by studying its primary or fundamental dimensions of system. Length L, Mass M, and time T are primary dimensions. If heat is involved in any problem of Fluid Mechanics, then temperature is also taken as primary dimension.

Secondary or Derived Quantities

These are the quantities which possess more than one fundamental dimension.

Ex:- Velocity $= \frac{\text{Distance}}{\text{Time}} = \frac{L}{T} = LT^{-1}$

(LT^{-1}) is called the dimensions of velocity.

The dimensions of mostly used physical quantities are given in table.

S No	Physical Quantity	Symbol	Dimensions
	a) Fundamental		
1	Length	L	L
2	Mass	M	M
3	Time	T	T
	b) Geometric		
4	Area	A	L^2
5	Volume	V	L^3
	c) Kinematic Quantities		
6	Velocity	V	LT^{-1}
7	Angular Velocity	ω	T^{-1}

Applied Hydraulics
(18CV43)

Module - 1

Dimensional Analysis : Dimensional analysis and similitude : Dimensional homogenity, Non Dimensional parameter, Rayleigh methods and Buckingham π theorem, dimensional analysis, choice of variables, examples on various applications.

Model Analysis : Model analysis, similitude, types of similarities, force ratios, similarity laws, model classification, Reynolds model, Froude's model, Euler's Model, Webber's model, Mach model, scale effects, distorted models, Numerical problems on Reynold's and Froude's Model.

Buoyancy and Flotation : Buoyancy, Force and Centre of Buoyancy, Metacentre and Metacentric height, Stability of submerged and floating bodies, Determination of Metacentric height, Experimental and theoretical method, Numerical problems.

SL.No	Physical Quantity	Symbol	Dimensions
8	Acceleration	a	LT^{-2}
9	Angular acceleration	α	T^{-2}
10	Discharge	Q	L^3T^{-1}
11	Acceleration due to gravity	g	LT^{-2}
12	Kinematic Viscosity	ν	L^2T^{-1}
	d) Dynamic Quantities		
13	Force	F	MLT^{-2}
14	Weight	W	MLT^{-2}
15	Density	ρ	ML^{-3}
16	Specific Weight	w	$ML^{-2}T^{-2}$
17	Dynamic Viscosity	μ	$ML^{-1}T^{-1}$
18	Pressure Intensity	p	$ML^{-1}T^{-2}$
19	Modulus of Elasticity	$\left\{\begin{matrix}K\\E\end{matrix}\right.$	$ML^{-1}T^{-2}$
20	Surface Tension	σ	MT^{-2}
21	Shear stress	τ	$ML^{-1}T^{-2}$
22	Work, Energy	W or E	ML^2T^{-2}
23	Power	P	ML^2T^{-3}
24	Torque	T	ML^2T^{-2}
25	Momentum	M	MLT^{-1}

Problem 1

Determine the dimensions of the quantities given below: i) Angular velocity, ii) Angular acceleration, iii) Discharge iv) Kinematic viscosity v) Force, vi) Specific weight and vii) Dynamic viscosity.

Soln: i) Angular velocity $= \dfrac{\text{Angle covered in radians}}{\text{Time}} = \dfrac{1}{T}$

$$= \underline{\underline{T^{-1}}}$$

ii) Angular acceleration $= \text{rad}/\text{sec}^2 = \dfrac{1}{T^2} = \underline{\underline{T^{-2}}}$

iii) Discharge $=$ Area x velocity $= L^2 \times \dfrac{L}{T} = \dfrac{L^3}{T} = \underline{\underline{L^2 T^{-1}}}$

iv) Kinematic Viscosity $(\nu) = \dfrac{\mu}{\rho}$

$\tau = \mu \dfrac{du}{dy}$ ← Newtons Law of Viscosity

$$\therefore \mu = \frac{\tau}{\frac{du}{dy}} = \frac{\text{Shear stress}}{\frac{L}{T} \times \frac{1}{L}}$$

$$= \frac{\text{Force}}{\text{Area}} \times T = \frac{\text{Mass} \times \text{acceleration}}{\text{Area}} \times T$$

$$\mu = \frac{M \times L/T^2}{L^2} \times T = \frac{M}{LT} = ML^{-1}T^{-1}$$

$$\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{L^3} = ML^{-3}$$

$$\nu = \frac{\mu}{\rho} = \frac{ML^{-1}T^{-1}}{ML^{-3}} = \underline{\underline{L^2 T^{-1}}}$$

v) Force $=$ mass x acceleration $= M \times \dfrac{L}{T^2} = \underline{\underline{MLT^{-2}}}$

vi) Specific weight $= \dfrac{\text{Weight}}{\text{Volume}} = \dfrac{\text{Force}}{\text{Volume}}$

$$= \frac{MLT^{-2}}{L^3} = \underline{\underline{ML^{-2}T^{-2}}}$$

vii) Dynamic viscosity, μ – derived in (iv)

$$\mu = \underline{\underline{ML^{-1}T^{-1}}}$$

Dimensional Homogeneity

An equation is said to be dimensionally homogeneous if dimensions are same on both sides of the equation. Such equations are independent of the system of units. Let us consider the equation, $V = \sqrt{2gH}$

Dimensions of LHS $= V = \frac{L}{T} = LT^{-1}$

Dimensions of RHS $= \sqrt{2gH} = \sqrt{\frac{L}{T^2} \times L} = \frac{L}{T} = LT^{-1}$

Dimensions of LHS = Dimensions of RHS $= LT^{-1}$

$\therefore$ Equation $V = \sqrt{2gH}$ is dimensionally homogeneous.

All derived / rational formulas are homogeneous.

Ex: $Q = AV$, $F = ma$, $P = \rho gh$

Non-Dimensional Parameter

Dimensionless numbers are those numbers which are obtained by dividing the inertia force by viscous force or gravity force or pressure force or surface tension force or elastic force. As this is a ratio of one force to the other force, it will be dimensionless number. It is also called Non-dimensional parameters. The following are important dimensionless numbers:

1) Reynold's number , 2) Froude's number

3) Euler's number 4) Weber's number

5) Mach's number.

Methods of Dimensional Analysis

If the number of variable involved in a physical phenomenon are known, then the relation among the variables can be determined by the following two methods:

1) Rayleigh's method and
2) Buckingham's π- theorem

Rayleigh's Method

This method is used for determining the expression for a variable which depends upon maximum three or four variables only.

Let X be a variable, which depends on X_1, X_2 and X_3 variables. Then according to Rayleigh's method, X is a function of X_1, X_2 and X_3 and mathematically it is written as $X = f\{X_1, X_2, X_3\}$

$$X = K X_1^a . X_2^b . X_3^c$$

where, K is constant and a, b, c are arbitrary powers

The values of a, b and c are obtained by comparing the powers of the fundamental dimension on both sides. Thus the expression is obtained for dependent variable.

Problem 2

The time period (t) of a pendulum depends upon the length (L) of the pendulum and acceleration due to gravity (g). Derive the expression for the time period.

Soln:
$$t = f\{L, g\}$$

$$\therefore t = K L^a . g^b$$

substituting dimensions on both sides

$$T^1 = K L^a (L T^{-2})^b$$

equating powers of M, L and T on both sides

Power of T, $1 = -2b$ $\quad \therefore b = -\frac{1}{2}$

Powers of L, $0 = a + b$, $\quad \therefore a = -b = \frac{1}{2}$

$$\therefore t = K L^{\frac{1}{2}} . g^{-1/2} = K\sqrt{\frac{L}{g}}$$

The value of K is determined from experiments, which is given as $K = 2\pi$

$$\boxed{t = 2\pi\sqrt{\frac{L}{g}}}$$

Problem 3 : Find an expression for the drag force on smooth sphere of diameter D, moving with a uniform velocity V in a fluid of density ρ and dynamic viscosity μ.

soln :- $F = K D^{a}, V^{b} \cdot \rho^{c} \cdot \mu^{d}$

$$MLT^{-2} = K L^{a} \cdot (LT^{-1})^{b} \cdot (ML^{-3})^{c} \cdot (ML^{-1}T^{-1})^{d}$$

Equating powers of M, L and T on both sides

Powers of M , $1 = c + d$

Powers of L, $1 = a + b - 3c - d$

Powers of T, $-2 = -b - d$

There are four unknowns (a, b, c, d) but equations are 3. Hence it is not possible to find the values of a, b, c and d. But 3 of them can be expressed in terms of 4th variable which is most important. Here viscosity is having a vital role and hence a, b, c are expressed in terms of d which is the power of viscosity.

$$c = 1 - d$$

$$b = 2 - d$$

$$a = 1 - b + 3c + d = 1 - 2 + d + 3 - 3d + d$$

$$= 2 - d$$

$$\therefore F = K D^{2-d} V^{2-d} \rho^{1-d} \mu^{d}$$

$$= K D^{2} V^{2} \rho (D^{-d} V^{-d} \rho^{-d}, \mu^{d})$$

$$= K \rho D^{2} V^{2} \left(\frac{\mu}{\rho V D}\right)^{d}$$

$$\therefore \boxed{F = K \rho D^{2} V^{2} \phi\left[\frac{\mu}{\rho V D}\right]}$$

Problem 4 : The resisting force R of a supersonic plane during flight can be considered as dependent upon the length of the aircraft l, velocity V, air viscosity μ, air density ρ and bulk modulus of air K.

Express the functional relationship between these variables and the resisting force.

N/m^2 $\frac{MLT^{-2}}{L^2}$

$\frac{E}{\epsilon}$

$K = \frac{\text{chg in pr}}{\text{chg in V}}$ = volumetric E

$\frac{F}{A} = \frac{ma}{L^5}$ MLT^{-2}

Soln:- $R = A\, l^a . V^b . \mu^c . \rho^d\; K^e$

A is non-dimensional constant

$$MLT^{-2} = A\, L^a . (LT^{-1})^b (ML^{-1}T^{-1})^c . (ML^{-3})^d . (ML^{-1}T^{-2})^e$$

Equating powers of M, L, T on both sides

Powers of M, $1 = c + d + e$

Powers of L, $1 = a + b - c - 3d - e$

Powers of T, $-2 = -b - c - 2e$

There are 5 unknowns but equations are only three. Expressing the 3 unknowns in terms of two unknowns (μ and K)

∴ Express the values of a, b and d in terms of c and e.

$$d = 1 - c - e$$

$$b = 2 - c - 2e$$

$$a = 1 - b + c + 3d + e = 1 - (2 - c - 2e) + c + 3(1 - c - e) + e$$

$$= 2 - c$$

$$\therefore R = A\, l^{2-c} . V^{2-c-2e} . \mu^c , \rho^{1-c-e} . K^e$$

$$= A\, l^2 . V^2 . \rho\, (l^{-c} . V^{-c} . \mu^c \rho^{-c}) . (V^{-2e} . \rho^{-e} . K^e)$$

$$= A\, l^2 V^2 \rho \left(\frac{\mu}{\rho V L}\right)^c . \left(\frac{K}{\rho V^2}\right)^e$$

$$\boxed{R = A \rho l^2 V^2 \phi\left[\left(\frac{\mu}{\rho V l}\right) . \left(\frac{K}{\rho V^2}\right)\right]}$$

Buckingham's π - Theorem

Statement: "If there are n variables (independent and dependent) in a physical phenomenon and if these variables contain m fundamental dimensions (M, L, T), then the variables are arranged into (n-m) dimensionless terms. Each term is called Buckingham's π - term."

Let $X_1, X_2, X_3 \ldots X_n$ are the variables involved in a physical problem. Let X_1 be the dependent variable and $X_2, X_3 \ldots X_n$ are the independent variables on which X_1 depends.

$$\therefore \quad X_1 = f(X_2, X_3, \ldots X_n) \qquad \text{--- (1)}$$

Also be written as, $f_1(X_1, X_2, X_3, \ldots, X_n) = 0$ — (2)

Eq^n (2) is a dimensionally homogeneous equation. It contains n variables. If there are m fundamental dimensions then according to Buckingham's π-theorem then eq^n(2) can be written in terms of number of dimensionless groups or π-terms in which number of π-terms is equal to $(n-m)$. Hence eq^n (2) becomes

$$f(\pi_1, \pi_2, \ldots, \pi_{n-m}) = 0 \qquad \text{--- (3)}$$

Each π-term contains $m+1$ variables, where m is the number of fundamental dimensions and is also called repeating variables. Let in the above case X_2, X_3 and X_4 are repeating variables if the fundamental dimensions m $(M, L, T) = 3$. Then each π-term is written as

$$\left.\begin{aligned} \pi_1 &= X_2^{a_1} \cdot X_3^{b_1} \cdot X_4^{c_1} \cdot X_1 \\ \pi_2 &= X_2^{a_2} \cdot X_3^{b_2} \cdot X_4^{c_2} \cdot X_5 \\ &\vdots \\ \pi_{n-m} &= X_2^{a_{n-m}} \cdot X_3^{b_{n-m}} \cdot X_4^{c_{n-m}} \cdot X_n \end{aligned}\right\} \qquad \text{--- (4)}$$

Each eq^n is solved by principle of dimensional homogeneity and values of a_1, b_1, c_1 etc are obtained. These values of π's are substituted in eq^n (4) and values of $\pi_1, \pi_2 \ldots \pi_{n-m}$ are obtained. These values of π's are substituted in eq^n (3). The final equation for the phenomenon is obtained by expressing any one of the π-terms as a function of others as

$$\pi_1 = \phi[\pi_2, \pi_3 \ldots, \pi_{n-m}]$$

or $$\pi_2 = \phi_1[\pi_1, \pi_3 \ldots, \pi_{n-m}] \qquad \text{--- (5)}$$

Choice of Repeating Variables

The number of repeating variables are equal to the number of fundamental dimensions of the problem.

The choice of repeating variables is governed by :-

1) The dependent variable should not be selected as repeating variable.

2) It should be chosen in such a way that one variable contains geometric property, other variable contains flow property and 3rd variable contains fluid property.

   Variables with geometric property are :- (Dimension)

   Ex :- length(l), diameter (d), height (H), area, Vol., MI.

   Variables with flow property :- (Kinematic) w.r to time

   Ex :- Velocity (V), Acceleration, discharge, angular velocity

   variables with fluid property : (Dynamic) w.r to mass.

   Ex : viscosity (μ,) density (ρ), surface tension, bulk modulus.

3) It should not form a dimensionless group

4) They together must have the same number of fundamental dimensions

5) No two repeating variables should have same dimensions.

Problem 5 : The resisting force R ~~depends~~ of a supersonic plane during flight can be considered as dependent upon the length of the aircraft l, velocity V, air viscosity μ, air density ρ and bulk modulus of air K. Express the functional relationship between these variables and the resisting force.

Solⁿ :- Step 1 :- $R = f(l, V, \mu, \rho, K)$

or $f_1(R, l, V, \mu, \rho, K) = 0$

Total number of variables $n = 6$

$R = MLT^{-2}$

$V = LT^{-1}$

$\mu = ML^{-1}T^{-1}$

$\rho = ML^{-3}$

$K = ML^{-1}T^{-2}$

Thus fundamental dimensions are M, L, T

∴ Number of fundamental dimensions $= m = 3$

Number of dimensionless π-terms $= n - m = 6 - 3 = 3$

Thus 3 π-terms say π_1, π_2 and π_3 are formed.

$$\therefore f_1(\pi_1, \pi_2, \pi_3) = 0$$

Step 2: Selected repeating variables are l, V and ρ

Step 3: $\therefore \pi_1 = l^{a_1} . V^{b_1} . \rho^{c_1} . R$

$\pi_2 = l^{a_2} . V^{b_2} . \rho^{c_2} . \mu$

$\pi_3 = l^{a_3} . V^{b_3} . \rho^{c_3} . K$

Step 4: Principle of homogeneity

1st term: $\pi_1 = M^0 L^0 T^0 = L^{a_1} (LT^{-1})^{b_1} (ML^{-3})^{c_1} . MLT^{-2}$

equating powers of M, L, T on both sides

Powers of M, $0 = c_1 + 1$ $\quad \therefore \boxed{c_1 = -1}$

" " L, $0 = a_1 + b_1 - 3c_1 + 1$

$a_1 = -b_1 + 3c_1 + (-1) = -2$, $\quad \therefore \boxed{a_1 = -2}$

Powers of T, $0 = -b_1 - 2$

$\therefore \boxed{b_1 = -2}$

$$\pi_1 = l^{-2} . V^{-2} . \rho^{-1} . R$$

$$\pi_1 = \frac{R}{\rho l^2 V^2}$$

2nd term: $\pi_2 = M^0 L^0 T^0 = L^{a_2} . (LT^{-1})^{b_2} . (ML^{-3})^{c_2} . ML^{-1}T^{-1}$

Powers of M, $0 = c_2 + 1$ $\quad \boxed{\therefore c_2 = -1}$

" " L, $0 = a_2 + b_2 - 3c_2 - 1$

Powers of T, $0 = -b_2 - 1$ $\quad \therefore \boxed{b_2 = -1}$

$a_2 = 1 + 3(-1) + 1$

$\boxed{a_2 = -1}$

$$\pi_2 = l^{-1} V^{-1} \rho^{-1} . \mu = \frac{\mu}{\rho l V}$$

3rd π term $\pi_3 = l^{a_3} V^{b_3} \rho^{c_3} K$

$$M^0L^0T^0 = L^{a_3} (LT^{-3})^{b_3} (ML^{-3})^{a_3} ML^{-1}T^{-2}$$

Powers of M, $0 = c_3 + 1$ $\boxed{\therefore c_3 = -1}$

" " L, $0 = a_3 + b_3 - 3c_3 - 1$

" " T, $0 = -b_3 - 2$, $\therefore \boxed{b_3 = -2}$

$$a_3 = 2 + 3(-1) + 1$$

$$\boxed{a_3 = 0}$$

$$\pi_3 = l^0 V^{-2} \rho^{-1} K = \frac{K}{V^2\rho}$$

Step 5: $$f_1\left(\frac{R}{\rho l^2 V^2}, \frac{\mu}{\rho l V}, \frac{K}{V^2\rho}\right) = 0$$

or $$\frac{R}{\rho l^2 V^2} = \phi\left[\frac{\mu}{\rho l V}, \frac{K}{V^2\rho}\right]$$

$$R = \rho l^2 V^2 \phi\left[\frac{\mu}{\rho l V}, \frac{K}{V^2\rho}\right]$$

Problem 6:

Using Buckingham's π-theorem, ST the velocity through a circular orifice is given by $V = \sqrt{2gH}\, \phi \sqrt{\frac{D}{H}, \frac{\mu}{\rho V H}}$, where H is the head causing flow, D is the diameter of the orifice, μ is co-efficient of viscosity, ρ is the mass density and g is acceleration due to gravity.

Soln:- $V = f(H, D, \mu, \rho, g)$ or $f_1(V, H, D, \mu, \rho, g) = 0$ — (1)

Total no. of variables, $n = 6$

Dimensions of each variable,

$V = LT^{-1}$, $H = L$, $D = L$

$\mu = ML^{-1}T^{-1}$, $\rho = ML^{-3}$, $g = LT^{-2}$

Thus, number of fundamental dimensions, $m = 3$

∴ Number of π = terms $= n - m = 6 - 3 = 3$

$\therefore f_1(\pi_1, \pi_2, \pi_3) = 0$ —— (2)

Choosing H, g, ρ as repeating variables, we get three π-terms as.

$$\pi_1 = H^{a_1} \cdot g^{b_1} \cdot \rho^{c_1} \cdot V$$

$$\pi_2 = H^{a_2} \cdot g^{b_2} \cdot \rho^{c_2} \cdot D$$

$$\pi_3 = H^{a_3} \cdot g^{b_3} \cdot \rho^{c_3} \cdot \mu$$

First π term

$$\pi_1 = H^{a_1} \cdot g^{b_1} \cdot \rho^{c_1} \cdot V$$

Substituting dimensions on both sides

$$M^0 L^0 T^0 = L^{a_1} \cdot (LT^{-2})^{b_1} \cdot (MT^{-3})^{c_1} \cdot (LT^{-1})$$

Equating the powers of M, L, T on both sides

Power of M, $0 = c_1$ $\quad \therefore \boxed{c_1 = 0}$

Power of L, $0 = a_1 + b_1 \cancel{+} - 3c_1 + 1$

Power of T, $0 = -2b_1 - 1$ $\quad \therefore \boxed{b_1 = -\frac{1}{2}}$

$$\therefore a_1 = -(-\tfrac{1}{2}) - 1 = -\tfrac{1}{2}$$

$$\boxed{a_1 = -\tfrac{1}{2}}$$

$$\therefore \pi_1 = H^{-1/2} \cdot g^{-1/2} \cdot \rho^0 \cdot V$$

$$\boxed{\pi_1 = \frac{V}{\sqrt{gH}}}$$

Second π-term

$$\pi_2 = H^{a_2} g^{b_2} \cdot \rho^{c_2} \cdot D$$

Substituting the dimensions on both sides

$$M^0 L^0 T^0 = L^{a_2} \cdot (LT^{-2})^{b_2} \cdot (ML^{-3})^{c_2} \cdot L$$

equating the powers of M, L, T

Power of M, $0 = c_2$ $\quad \therefore \boxed{c_2 = 0}$

Power of L, $0 = a_2 + b_2 - 3c_2 + 1$

Power of T, $0 = -2b_2$ $\quad \therefore \boxed{b_2 = 0}$

$$a_2 = -b_2 + 3c_2 - 1 = -1$$

$$\boxed{a_2 = -1}$$

$$\therefore \pi_2 = H^{-1} \cdot g \cdot \rho^0 \cdot D$$

$$\boxed{\pi_2 = D/H}$$

Third π term

$$\pi_3 = H^{a_3} \cdot g^{b_3} \cdot \rho^{c_3} \cdot \mu$$

substituting the dimensions on both sides

$$M^0L^0T^0 = L^{a_3} \cdot (LT^{-2})^{b_3} \cdot (ML^{-3})^{c_3} \cdot ML^{-1}T^{-1}$$

Equating the powers of M, L, T on both sides

Power of M, $0 = c_3+1$, $\boxed{c_3=-1}$

Power of T, $0 = -2b_3-1$, $\boxed{b_3 = -1/2}$

Power of L, $0 = a_3+b_3-3c_3-1$

$$a_3 = -b_3+3c_3+1 = 1/2-3+1 = -3/2$$

$$\boxed{a_3 = -3/2}$$

$$\therefore \pi_3 = H^{-3/2} g^{-1/2} \cdot \rho^{-1} \cdot \mu = \frac{\mu}{H^{3/2}\rho\sqrt{g}} = \frac{\mu}{H\rho\sqrt{gH}} = \frac{\mu V}{H\rho V\sqrt{gH}}$$

$$\boxed{\pi_3 = \frac{\mu}{H\rho V} \cdot \pi_1}$$

Substituting π_1, π_2 and π_3 in eq^n (2)

$$f_1\left(\frac{V}{\sqrt{gH}}, \frac{D}{H}, \pi_1\frac{\mu}{H\rho V}\right) = 0$$

or $$\frac{V}{\sqrt{gH}} = \phi\left[\frac{D}{H}, \pi_1\frac{\mu}{H\rho V}\right]$$

$$\boxed{V = \sqrt{2gH}\,\phi\left[\frac{D}{H}, \frac{\mu}{H\rho V}\right]}$$

Multiplying by a constant does not change the character of π-terms.

Advantages of Buckinghams π Theorem over Rayleigh's:

1) In Rayleigh's method, no. of dimensionless groups are not known but known in advance in Buckinghams.

2) If variables are more than 3, elaborate procedure in Rayleighs whereas simple procedure in Buckingham's and less time consuming.

MODULE - 2

Open Channel Flow Hydraulics

Uniform flow: Introduction, Classification of flow through channels, Chezy's and Manning's equation for flow through open channel, Most economical channel sections. Uniform flow through Open channels, Numerical problems. Specific Energy and specific energy curve, Critical flow and corresponding critical parameters, Numerical problems.

Flow in open channels is defined as the flow of a liquid with a free surface. A free surface is a surface having constant pressure such as atmospheric pressure. Thus a liquid flowing at atmospheric pressure through a passage is known as flow in open channels.

Classification of flow in channels

The flow in open channel is classified into the following types

(1) Steady flow and unsteady flow,
(2) Uniform flow and non-uniform flow
(3) Laminar flow and turbulent flow
(4) Sub-critical, critical & super-critical flow.

Steady flow and unsteady flow:

If the flow characteristics such as depth of flow, velocity of flow, rate of flow at any point in open channel flow do not change with respect to time, the flow is said to be steady flow.

If at any point in open channel flow, the velocity of flow, depth of flow or rate of flow changes with respect to time, the flow is said to be unsteady flow.

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Uniform flow and Non-uniform flow

If for a given length of the channel, the velocity of flow, depth of flow, slope of the channel and cross-section remain constant, the flow is said to be uniform.

If for a given length of the channel, the velocity of flow, depth of flow etc do not remain constant, the flow is said to be non-uniform flow.

Laminar flow and Turbulent flow

The flow in open channel is said to be laminar if the Reynold number (Re) is less than 500 or 600.

If the Reynold number is more than 2000, the flow is said to be turbulent flow.

Sub-critical, Critical & super critical flow

The flow in open channel is said to be sub-critical if the Froude number (Fe) is less than 1.0

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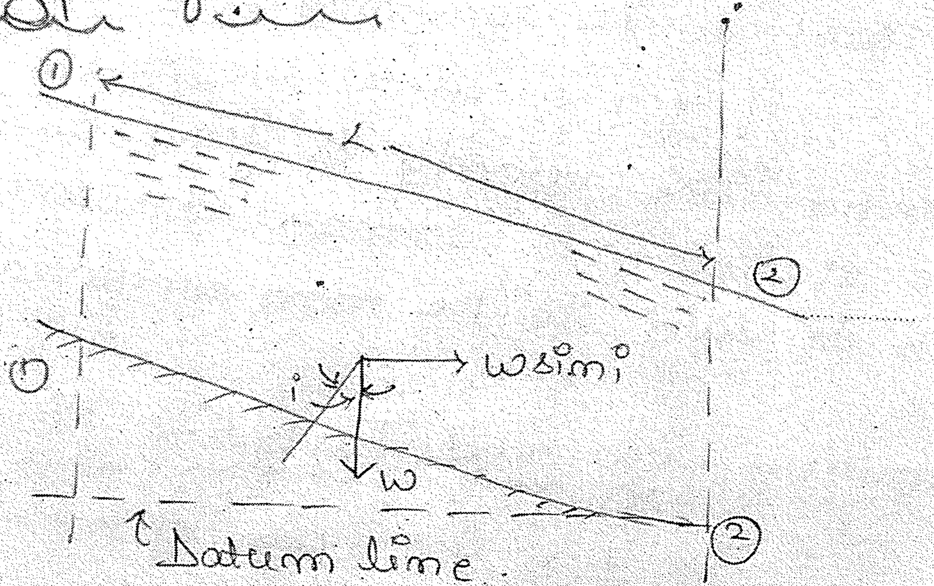
The flow is called critical if $F_e = 1.0$ and if $F_e > 1.0$, the flow is called super critical flow.

Discharge through open channel by Chezy's formula



Consider uniform flow of water in a channel as shown in fig. As the flow is uniform, it means the velocity, depth of flow and area of flow will be constant for a given length of the channel. Consider sections 1-1 and 2-2.

Let, L = Length of channel
A = area of flow of water
i = slope of the bed
V = Mean velocity of flow of water

P = Wetted perimeter of the cross section

f - frictional resistance per unit velocity per unit area.

The weight of water between sections 1-1 and 2-2

W = Specific weight of water × vol. of water

= w × A × L

Component of W along direction of flow = W × sin i = wAL sin i

Frictional resistance against motion of water = f × surface area × $(\text{velocity})^n$

The value of n is found experimentally equal to 2 and surface area = P × L

∴ Frictional resistance against motion = $f \times P \times L \times V^2$

The forces acting on the water between sections 1-1 and 2-2 are

(1) Component of weight of water along the direction of flow

(2) Friction resistance against flow of water

(3) Pressure force at section 1-1

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(4) Pressure force at section 2-2.

As the depths of water at the sections 1-1 and 2-2 are the same, the pressure forces on these two sections are same and acting in the opposite direction. Hence they cancel each other. In case of uniform flow, the velocity of flow is constant for the given length of the channel. Hence there is no acceleration acting on the water. Hence the resultant force acting in the direction of flow must be zero.

∴ Resolving all forces in the direction of flow, we get

$$wAL\sin i - f \times P \times L \times V^2 = 0$$

$$wAL\sin i = f \times P \times L \times V^2$$

Or

$$V^2 = \frac{wAL\sin i}{f \times P \times L} = \frac{w}{f} \times \frac{A}{P} \times \sin i$$

Or

$$V = \sqrt{\frac{w}{f}} \times \sqrt{\frac{A}{P} \times \sin i} \quad \text{———} \ ①$$

But $\frac{A}{P} = m$

= hydraulic mean depth
Or hydraulic radius

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$$\sqrt{\frac{w}{t}} = C = \text{Chezy's constant}$$

Substituting the values of $\frac{A}{P}$ and $\sqrt{\frac{w}{t}}$ in eqn ①, $V = C\sqrt{m \sin i}$

For small values of i,

$$\sin i \simeq \tan i \simeq i \quad \therefore V = C\sqrt{mi}$$

∴ Discharge, Q = area x velocity = $A \times V$

$$\boxed{Q = A \times C\sqrt{mi}}$$

Problems

(1) Find the velocity of flow and rate of flow of water through a rectangular channel of 6m wide and 3m deep, when it is running full. The channel is having bed slope as 1 in 2000. Take Chezy's constant C = 55

⇒ Width of rectangular channel $b = 6m$

Depth of channel, $d = 3m$

∴ Area, $A = 6 \times 3 = 18m^2$

Bed slope, i = 1 in 2000 = $\frac{1}{2000}$

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Chezy's constant, $C = 55$

Perimeter, $P = b + 2d = 6 + 2 \times 3 = 12m$

$\therefore$ Hydraulic mean depth, $m = \frac{A}{P}$

$= \frac{18}{12} = 1.5m$

Velocity of flow, $V = C\sqrt{mi}$

$= 55\sqrt{1.5 \times \frac{1}{2000}}$

$\boxed{V = 1.506 \, m/s}$

Rate of flow, $Q = V \times \text{Area}$

$= 1.506 \times 18$

$\boxed{Q = 27.108 \, m^3/s}$

(2) Find the slope of the bed of a rectangular channel of width 5m when depth of water is 2m and rate of flow is given as $20m^3/s$. Take Chezy's constant, $C = 50$

$\Rightarrow$ width of channel, $b = 5m$

depth of water, $d = 2m$

Rate of flow, $Q = 20m^3/s$

Chezy's constant $C = 50$

Let the bed slope $= i$

$Q = AC\sqrt{mi}$

$A = \text{area} = b \times d = 5 \times 2 = 10 m^2$

$m = \frac{A}{P} = \frac{10}{b+2d} = \frac{10}{5+(2\times2)} = \frac{10}{5+4} = \frac{10}{9} m$

$20 = 10 \times 50 \times \sqrt{\frac{10}{9} \times i}$

or $\sqrt{\frac{10}{9} i} = \frac{20}{500} = \frac{2}{50}$

Squaring both sides, we have $\frac{10}{9} i = \frac{4}{2500}$

$i = \frac{4}{2500} \times \frac{9}{10} = \frac{36}{25000} = \frac{1}{\frac{25000}{36}}$

$$\boxed{i = \frac{1}{694.44}}$$

(3) A flow of water of 100 litres/sec flows down in a rectangular flume of width 600mm and having adjustable bottom slope. If Chezy's constant C is 56, find the bottom slope necessary for uniform flow with a depth of flow of 300mm. Also find the conveyance K of the flume.

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$\Rightarrow$ Discharge, $Q = 100$ litres/s $= \frac{100}{1000}$

$Q = 0.10 m^3/s$

Width of channel, $b = 600 mm = 0.6 m$

depth of flow, $d = 300 mm = 0.30 m$

$\therefore$ Area of flow, $A = b \times d$

$= 0.6 \times 0.3$

$= 0.18 m^2$

Chezy's constant, $C = 56$

Let the slope of bed $= i$

Hydraulic mean depth, $m = \frac{A}{P}$

$= \frac{0.18}{b+2d}$

$= \frac{0.18}{0.6 + 2 \times 0.30}$

$= \frac{0.18}{1.2} = 0.15 m$

$Q = AC\sqrt{mi}$

$0.10 = 0.18 \times 56 \times \sqrt{0.15 \times i}$

$\sqrt{0.15i} = \frac{0.10}{0.18 \times 56}$

squaring both sides,

$0.15i = \left(\frac{0.10}{0.18 \times 56}\right)^2 = 0.000098418$

$i = \frac{0.000098418}{0.15} = 0.0006512$

$\boxed{i = \frac{1}{1524}}$

Conveyance K of the channel.

$Q = AC\sqrt{mi}$

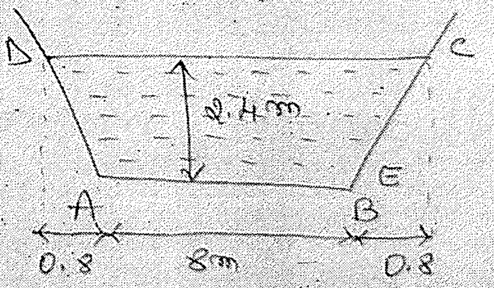
$Q = K\sqrt{i}$

where $K = AC\sqrt{m}$

$K = 0.18 \times 56 \times \sqrt{0.15}$

$\boxed{K = 3.903 \ m^3/s}$

(4) Find the discharge through a trapezoidal channel of width 8m & side slope of 1 horizontal to 3 vertical. The depth of flow of water is 2.4m and value of Chezy's constant, C = 50. The slope of the bed of the channel is given 1 in 4000.



⇒ width, $b = 8m$

side slope $= 1:3$

depth, $d = 2.4m$

Chezy's constant, $C = 50$

bed slope, $i = \frac{1}{4000}$

from fig. $CE = 2.4$

horizontal distance $BE = 2.4 \times \frac{1}{3} = 0.8m$

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∴ Top width of the channel,

$CD = AB + 2 \times BE = 8.0 + 2 \times 0.8 = 9.6\,m$

∴ area of trapezoidal channel, ABCD is given as,

$$A = (AB + CD) \times \frac{CE}{2} = (8 + 9.6) \times \frac{2.4}{2}$$

$$= 17.6 \times 1.2$$

$$\boxed{A = 21.12\,m^2}$$

Wetted perimeter, $P = AB + BC + AD$

$= AB + 2BC \quad (\because BC = AD)$

But, $BC = \sqrt{BE^2 + CE^2} = \sqrt{(0.8)^2 + (2.4)^2}$

$BC = 2.529\,m$

$P = 8.0 + (2 \times 2.529) = 13.058\,m$

Hydraulic mean depth, $m = \frac{A}{P} = \frac{12.12}{13.058}$

$m = 1.617\,m$

$$Q = AC\sqrt{mi}$$

$$= 21.12 \times 50 \sqrt{1.617 \times \frac{1}{4000}}$$

$$\boxed{Q = 21.23\,m^3/s}$$

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(5) Find the bed slope of trapezoidal channel of bed width 6m, depth of water 3m and side slope of 3 horizontal to 4 vertical, when the discharge through the channel is 30m³/s. Take chezy's constant, C = 70

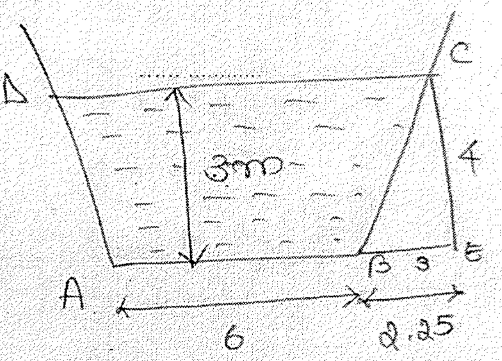
⟹ bed width, $b = 6.0m$

depth of flow, $d = 3.0m$

side slope = 3hor to 4 vertical

$Q = 30m^3/s$

$C = 70$



from fig, CE = 3m

distance, $BE = 3 \times \frac{3}{4}$

$= \frac{9}{4} = 2.25m$

∴ Top width, $CD = AB + 2 \times BE$

$= 6 + 2 \times 2.25$

$= 10.50m$

wetted perimeter, $P = AD + AB + BC$

$= AP + 2BC$

$= 6 + 2\sqrt{2.25^2 + 3^2}$

$= 13.5m$

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Area of flow, $\frac{(AB+CD)\,CE}{2} = \frac{6+10.50}{2} \times 3.0$

$= 24.75\,m^2$

Hydraulic mean depth, $m = \frac{A}{P}$

$= \frac{24.75}{13.50} = 1.833$

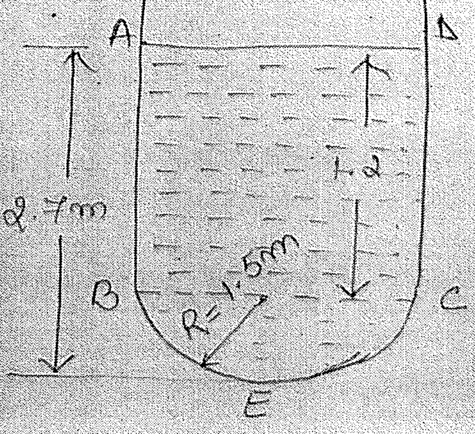
$Q = AC\sqrt{mi}$

$30 = 24.75 \times 70 \times \sqrt{1.833 \times i}$

$= 2345.6\sqrt{i}$

$i = \left(\frac{30}{2345.6}\right)^2 = \frac{1}{\left(\frac{2345.6}{30}\right)^2} = \frac{1}{6133}$

(6) Find the discharge of water through the channel shown in fig. Take the value of Chezy's constant = 60 and slope of the bed as 1 in 2000.



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$\Rightarrow C = 60$

$i = 1/2000$

$A =$ area ABCD + area BEC

$= (1.2 \times 3.0) + \frac{\pi R^2}{2}$

$= 3.6 + \frac{(1.5)^2}{2}$

$= 7.134 \, m^2$

wetted perimeter, $P = AB + BEC + CD$

$= 1.2 + \pi R + 1.2$

$= 1.2 + (\pi \times 1.5) + 1.2$

$= 7.1124 \, m$

Hydraulic mean depth, $m = \frac{A}{P} = \frac{7.134}{7.1124}$

$= 1.003$

$Q = AC\sqrt{mi}$

$= 7.134 \times 60 \times \sqrt{1.003 \times \frac{1}{2000}}$

$$\boxed{Q = 9.585 \, m^3/s}$$

(7) Find the rate of flow of water through a V-shaped channel as shown in fig. Take the value of C = 55 and slope of the bed 1 in 2000

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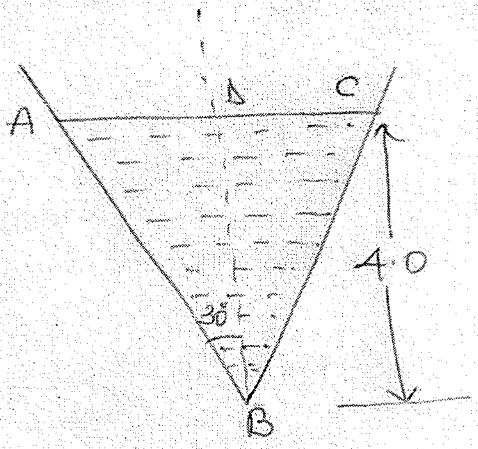
$\Rightarrow C = 55$

$i = \frac{1}{1000}$

$d = 4.0\,m$

$\underline{\angle ABD} = \underline{\angle CBD} = 30^\circ$



A = area of ABC

$= 2 \times$ area ABD

$= \frac{2 \times AD \times BD}{2} = AD \times BD$

$= BD \,\text{Tan}\, 30 \times BD \qquad \left[\because \text{Tan}\, 30 = \frac{AD}{BD},\quad AD = BD\,\text{Tan}\,30\right]$

$= 4\,\text{Tan}\,30 \times 4$

$= 9.2376\,m^2$

wetted perimeter, $P = AB + BC = 2AB$

$= 2\sqrt{BD^2 + AD^2}$

$= 2\sqrt{4.0^2 + (4\,\text{Tan}\,30)^2}$

$= 2\sqrt{16 + 5.33}$

$= 9.2375\,m$

$\therefore$ Hydraulic mean depth, $m = \frac{A}{P}$

$= \frac{9.2376}{9.2375} = 1.0\,m$

$Q = AC\sqrt{mi}$

$= 9.2376 \times 55\sqrt{1 \times \frac{1}{1000}}$

$= 16.066\,m^3/s$

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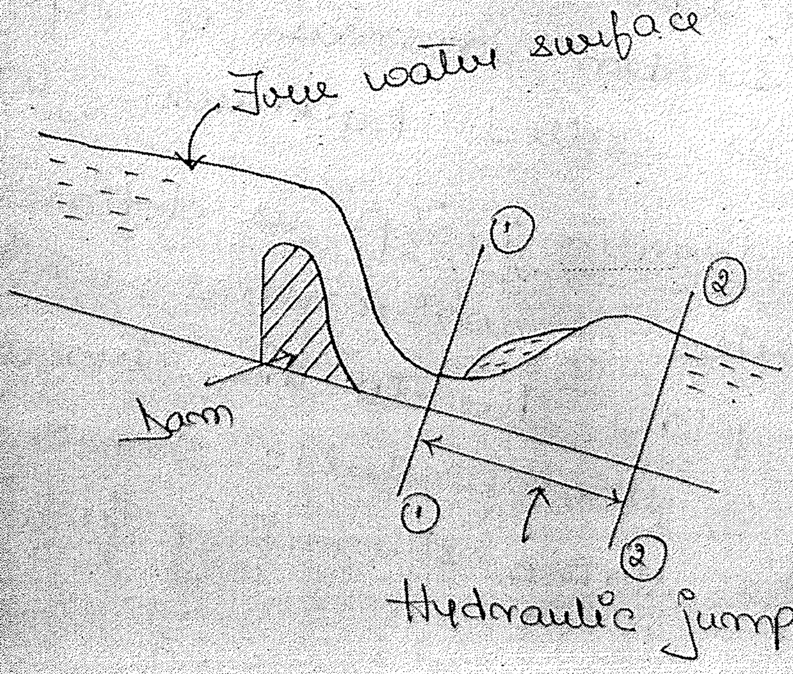
MODULE - 3

Non-Uniform Flow: Hydraulic jump, Expressions for conjugate depths & Energy loss, Numerical problems. Gradually varied flow, Equation, Back water curve and afflux, Description of water curves or profiles, Mild, steep, critical, horizontal and adverse slope profiles, Numerical problems on identifying the flow profiles.

Hydraulic jump



Consider the flow of water over a dam as shown in fig. The height of water at the section 1-1 is small. As we move towards downstream, the height or depth of water increases rapidly over a short length of the channel. This is because at the section 1-1, the flow is a shooting flow as the depth of water at section 1-1 is less than Critical depth. Shooting flow is an unstable type of flow and does not continue on the downstream side. Then this shooting will convert itself into a streaming or tranquil flow and hence depth of water will increase. This sudden increase of depth of water is called hydraulic jump.

Hydraulic jump is defined as, the rise of water level, which takes place due to the transformation of the unstable shooting flow to the stable streaming flow.

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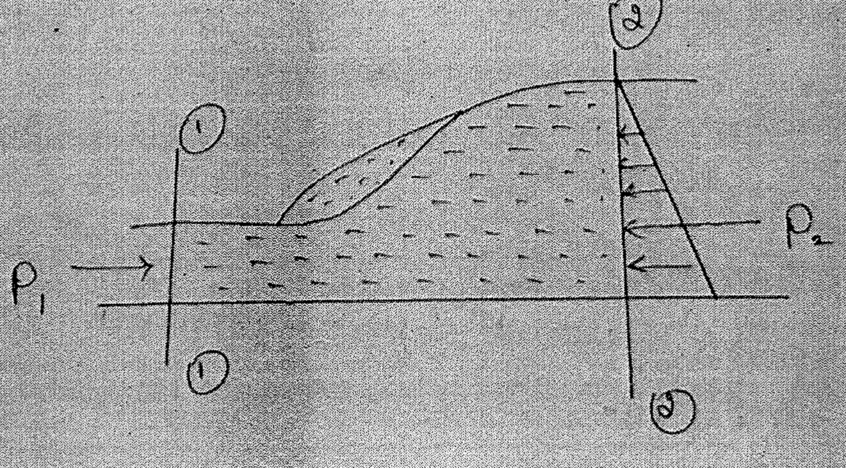
Expression for Depth of Hydraulic jump

Before deriving an expression for the depth of hydraulic jump, the following assumptions are made

(1) The flow is uniform and pressure distribution is due to hydrostatic before and after the jump.

(2) Losses due to friction on the surface of the bed of the channel are small and hence neglected.

(3) The slope of the bed of the channel is small, so that the component of the weight of the fluid in the direction of flow is negligibly small.



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Consider a hydraulic jump formed in a channel of horizontal bed as shown in fig. Consider two sections 1-1 and 2-2 before and after hydraulic jump.

Let d_1 = depth of flow at section 1-1
d_2 = depth of flow at section 2-2
V_1 = velocity of flow at section 1-1
V_2 = velocity of flow at section 2-2
$\bar{Z}_1$ = depth of centroid of area at section 1-1 below free surface
$\bar{Z}_2$ = depth of centroid of area at section 2-2 below free surface
A_1 = area of c/s at section 1-1
A_2 = area of c/s at section 2-2

Consider unit width of the channel. The forces acting on the mass of water between sections 1-1 and 2-2 are

(i) Pressure force, P_1 on section 1-1
(ii) Pressure force, P_2 on section 2-2
(iii) Frictional force on the floor of the channel, which is assumed to be negligible.

Let, q = discharge per unit width

$$= V_1 d_1 = V_2 d_2 \quad \text{———} ①$$

Now pressure force P_1 on section 1-1

$$= \rho g A_1 \bar{Z}_1 = \rho g d_1 \times 1 \times \frac{d_1}{2}$$

$$= \frac{\rho g d_1^2}{2} \quad \left[\because A_1 = d_1 \times 1,\ \bar{Z}_1 = \frac{d_1}{2} \right]$$

Similarly pressure force on section 2-2

$$P_2 = \rho g A_2 \bar{Z}_2$$

$$= \rho g\, d_2 \times 1 \times \frac{d_2}{2} = \frac{\rho g d_2^2}{2}$$

Net force acting on the mass of water between sections 1-1 and 2-2

$= P_2 - P_1$ (P_2 is greater than P_1 & d_2 is greater than d_1)

$$= \frac{\rho g d_2^2}{2} - \frac{\rho g d_1^2}{2}$$

$$= \frac{\rho g}{2}\left[d_2^2 - d_1^2 \right] \quad \text{———} ②$$

But from momentum principle, the net force acting on a mass of fluid must be equal to the rate of change of momentum in the same section.

∴ Rate of change of momentum in the direction of force

= mass of water per sec × change of velocity in direction of force

Now mass of water per second

= ρ × discharge per unit width × width

$m = \rho \times V$ Q/

kg/s $= \rho \times m^3/s \times \frac{1}{m} \times m$

kg/m³

$V = q \times b$

$m^3/s \times \frac{1}{m}$

$= \rho \times q \times 1$

$= \rho q$ m³/s.

Change of velocity in the direction of force $= (V_1 - V_2)$

∴ Rate of change of momentum in the direction of force $= \rho q (V_1 - V_2)$ — ③

Hence according to momentum principle, the expression given by eqⁿ ② is equal to the expression given by eqⁿ ③

or $$\frac{\rho g}{2}(d_2^2 - d_1^2) = \rho q (V_1 - V_2)$$

But from eqⁿ ① $V_1 = \frac{q}{d_1}$ & $V_2 = \frac{q}{d_2}$

$$\therefore \frac{\rho g}{2}(d_2^2 - d_1^2) = \rho q \left(\frac{q}{d_1} - \frac{q}{d_2}\right)$$

Or $$\frac{g}{2}(d_2+d_1)(d_2-d_1) = q^2\left(\frac{d_2-d_1}{d_1d_2}\right)$$

÷ by ρ

Or $$\frac{g}{2}(d_2+d_1) = \frac{q^2}{d_1d_2}$$

÷ by (d_2-d_1)

Or $$(d_2+d_1) = \frac{2q^2}{gd_1d_2} \quad \text{———} \; ④$$

Multiplying both sides by d_2

$$d_2^2 + d_1d_2 = \frac{2q^2}{gd_1} \quad \text{or} \quad d_2^2 + d_1d_2 - \frac{2q^2}{gd_1} = 0 \quad \text{———} \; ⑤$$

Eqⁿ ⑤ is a quadratic equation in d_2 and hence its solution is

$$d_2 = \frac{-d_1 \pm \sqrt{d_1^2 - 4\times1\left(\frac{-2q^2}{gd_1}\right)}}{2\times1}$$

$$= \frac{-d_1 \pm \sqrt{d_1^2 + \frac{8q^2}{gd_1}}}{2}$$

$$= \frac{-d_1}{2} \pm \sqrt{\frac{d_1^2}{4} + \frac{2q^2}{gd_1}}$$

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The two roots of the equation are

$$-\frac{d_1}{2}-\sqrt{\frac{d_1^2}{4}+\frac{2q^2}{gd_1}} \quad \text{and} \quad -\frac{d_1}{2}+\sqrt{\frac{d_1^2}{4}+\frac{2q^2}{gd_1}}$$

First root is not posible as it gives -ve depth. Hence

$$d_2=-\frac{d_1}{2}+\sqrt{\frac{d_1^2}{4}+\frac{2q^2}{gd_1}}$$

$$=\frac{-d_1}{2}+\sqrt{\frac{d_1^2}{4}+\frac{2\times(V_1d_1)^2}{gd_1}}$$

$$=\frac{-d_1}{2}+\sqrt{\frac{d_1^2}{4}+\frac{2V_1^2d_1}{g}}$$

$\therefore$ Depth of Hydraulic jump $=(d_2-d_1)$

Expression for Loss of Energy due to Hydraulic jump

When hydraulic jump takes place, a loss of energy due to eddies formation and turbulence occurs.

This loss of energy is equal to the difference of specific energies at sections 1-1 and 2-2.

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Loss of energy due to hydraulic jump

$h_L = E_1 - E_2$

$= \left[d_1 + \frac{V_1^2}{2g}\right] - \left[d_2 + \frac{V_2^2}{2g}\right] \quad \left[\because E_1 = d_1 + \frac{V_1^2}{2g}\right.$

$= \left[\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right] - (d_2 - d_1)$

$= \left[\frac{q^2}{2gd_1^2} - \frac{q^2}{2gd_2^2}\right] - (d_2 - d_1)$

$\left[\because V_1 = \frac{q}{d_1} \ \& \ V_2 = \frac{q}{d_2}\right]$

$= \frac{q^2}{2g}\left[\frac{1}{d_1^2} - \frac{1}{d_2^2}\right] - (d_2 - d_1)$

$= \frac{q^2}{2g}\left[\frac{d_2^2 - d_1^2}{d_1^2 d_2^2}\right] - (d_2 - d_1)$ ——— ⑥

But from eqⁿ ④, $q^2 = gd_1d_2\frac{(d_2+d_1)}{2}$

Sub the value of q^2 in eqⁿ ⑥, we get

Loss of energy, $h_L = gd_1d_2\frac{(d_2+d_1)}{2} \times \frac{d_2^2 - d_1^2}{2gd_1^2d_2^2} - (d_2 - d_1)$

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$$= \frac{(d_2+d_1)(d_2^2-d_1^2)}{4d_1d_2} - (d_2-d_1)$$

$$= \frac{(d_2+d_1)(d_2+d_1)(d_2-d_1)}{4d_1d_2} - (d_2-d_1)$$

$$= (d_2-d_1)\left[\frac{(d_2+d_1)^2}{4d_1d_2} - 1\right]$$

$$= (d_2-d_1)\left[\frac{d_2^2+d_1^2+2d_1d_2-4d_1d_2}{4d_1d_2}\right]$$

$$= (d_2-d_1)\,\frac{(d_2-d_1)^2}{4d_1d_2}$$

$$\boxed{h_L = \frac{(d_2-d_1)^3}{4d_1d_2}}$$

Problems

(1) The depth of flow of water, at a certain section of a rectangular channel of 4m wide, is 0.5m. This discharge through the channel is $16\,m^3/s$. If a hydraulic jump takes place on the downstream side, find the depth of flow after the jump.

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$\Rightarrow$ $b = 4m$, $Q = 16 m^3/s$

depth of flow before jump, $d_1 = 0.5m$

discharge per unit width, $q = \frac{Q}{b} = \frac{16}{4}$

$q = 4m^2/s$

Let, depth of flow after jump $= d_2$

$$d_2 = \frac{-d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2q^2}{gd_1}}$$

$$d_2 = \frac{-0.5}{2} + \sqrt{\frac{0.5^2}{4} + \frac{2 \times 4^2}{9.81 \times 0.5}}$$

$$d_2 = -0.25 + \sqrt{0.0625 + 6.5239}$$

$$\boxed{d_2 = 2.316m}$$

(2) The depth of flow of water, at a certain section of a rectangular channel of 2m wide, is 0.3m. The discharge through the channel is 1.5m³/s. Determine whether a hydraulic jump will occur and if so, find its height and loss of energy per kg of water.

$\Rightarrow$ $d_1 = 0.3m$

$b = 2m$

$Q = 1.5 m^3/s$

$$q = \frac{Q}{b} = \frac{1.5}{2} = 0.75 m^2/s$$

$$h_c = \left[\frac{q^2}{g}\right]^{1/3} = \left[\frac{0.75^2}{9.81}\right]^{1/3} = 0.3859$$

Now the depth on the upstream side is 0.3m. This depth is less than critical depth and hence hydraulic jump will occur.

$$d_2 = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2q^2}{gd_1}}$$

$$d_2 = \frac{-0.3}{2} + \sqrt{\frac{0.3^2}{4} + \frac{2\times 0.75^2}{9.81\times 0.3}}$$

$$\boxed{d_2 = 0.4862 m}$$

$\therefore$ Height of hydraulic jump $= d_2 - d_1$

$= 0.4862 - 0.3$

$= 0.1862 m$

Loss of energy, $h_L = \frac{(d_2 - d_1)^3}{4d_1d_2}$

$$\boxed{h_L = 0.01106 m-kg/kg}$$

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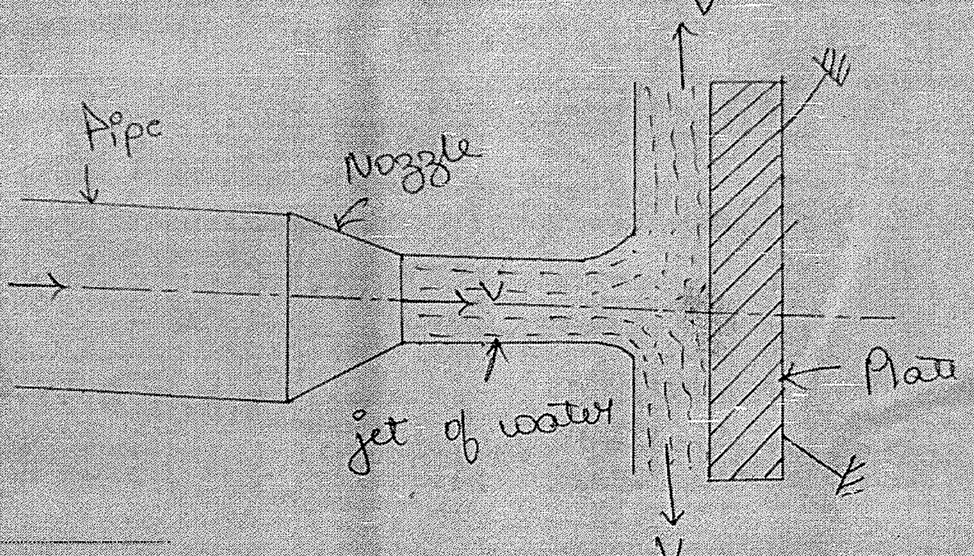
MODULE-4

Force exerted by the jet on a stationary vertical plate



Consider a jet of water coming out from the nozzle, strikes a flat vertical plate as shown in fig.

Let V = velocity of the jet

d = dia. of the jet

a = area of c/s of the jet $= \frac{\pi}{4} d^2$

The jet after striking the plate, will move along the plate. But the plate is at right angles to the jet. Hence the jet after striking, will get deflected through 90°. Hence the component of the velocity of jet, in the direction of jet, after striking will be zero.

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The force excited by the jet on the plate in the direction of jet

F_x = rate of change of momentum in the direction of force

$$= \frac{\text{initial momentum} - \text{final momentum}}{\text{Time}}$$

$$= \frac{\text{mass} \times \text{initial velocity} - \text{mass} \times \text{final velocity}}{\text{Time}}$$

$$= \frac{\text{mass}}{\text{Time}} \left[\text{initial velocity} - \text{final velocity} \right]$$

$$= \frac{\text{mass}}{\text{sec}} \left[\text{vel. of jet before striking} - \text{vel. of jet after striking} \right]$$

$$= \rho a V [V - 0] \qquad \left[\because \text{mass/sec} = \rho a V \right.$$

$$\boxed{F_x = \rho a V^2}$$

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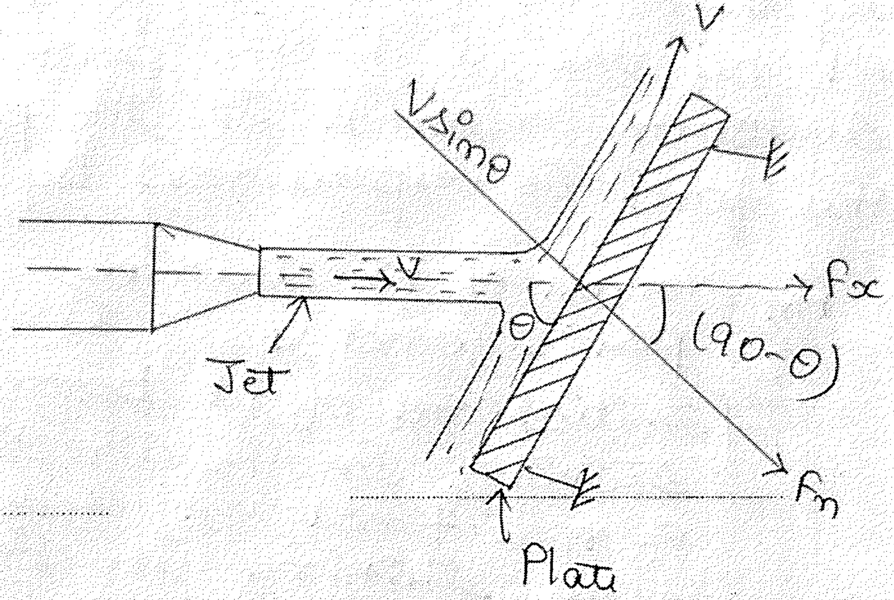
1(b)

Force exerted by a jet on stationary inclined flat plate



Let a jet of water, coming out from the nozzle, strikes an inclined flat plate as shown in fig.

Let V = vel. of jet in the direction of x

θ = angle b/w the jet and plate

a = area of c/s of the jet

Mass of water per sec striking the plate $= \rho \times aV$

If the plate is smooth & if it is assumed that there is no loss of energy due to impact of the jet, then jet will move over the plate after striking with a velocity equal to initial velocity i.e with a velocity V. Let us find the force exerted by the jet on the plate in the direction normal to the plate. Let this force is represented by Fn

Then Fn = mass of jet striking per second ×
[initial vel. of jet before striking in the direction of n − final vel. of jet after striking in the direction of n]

$= \rho a v [V \sin\theta - 0] = \rho a v^2 \sin\theta$

This force can be resolved into two components, one in the direction of the jet and other perpendicular to the direction of flow. Then we have,

Fx = Component of Fn in the direction of flow

$= F_n \cos(90 - \theta)$

$= \rho A V^2 \sin\theta \times \sin\theta$

$$\boxed{F_x = \rho A V^2 \sin^2\theta}$$

1(c)

F_y = component of F_n perpendicular to flow

$= F_n \sin(90-\theta)$

$$\boxed{F_y = \rho A V^2 \sin\theta \cos\theta}$$

MODULE-4

Impact of jet on Curved vanes:

Introduction, Impulse - momentum equation, Direct impact of a jet on stationary and moving curved vanes. Introduction to concept of velocity triangles, impact of jet on a series of curved vanes - Problems.

Turbines - Impulse turbines:

Introduction to turbines, General lay out of a hydro - electric plant, Heads & efficiencies, classification of turbines, Pelton wheel - components, working principle and velocity triangles, Max. power, efficiency, working proportions - Numerical problems.

The liquid comes out in the form of a jet from the outlet of a nozzle, which is fitted to a pipe through which the liquid is flowing under pressure. If some plate, which may be fixed or moving, is placed in the path of the jet, a force is exerted by the jet on the plate. This force is obtained from

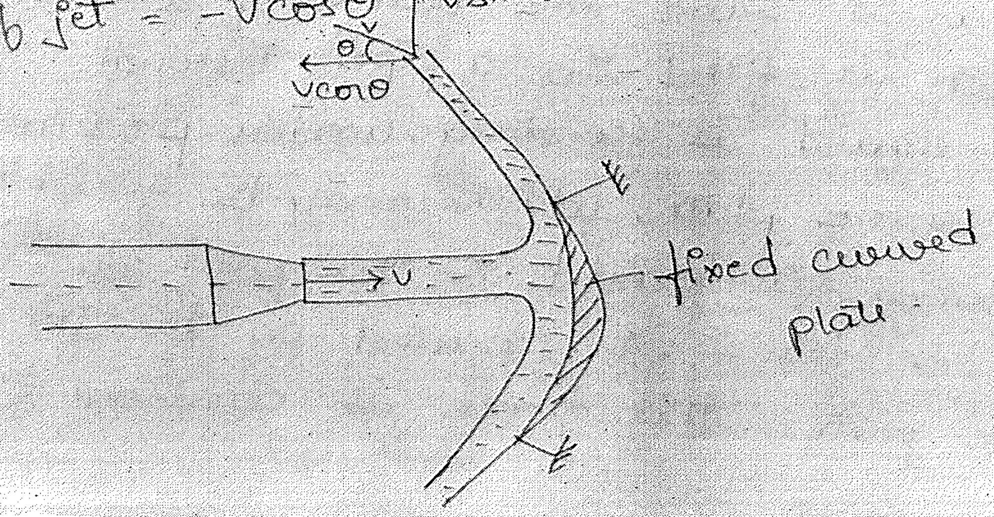
Newton's second law of motion or from impulse - momentum equation.

Force exerted by a Jet on Stationary Curved Plate

(A) Jet strikes the curved plate at the centre.

Let a jet of water strikes a fixed curved plate at the centre as shown in fig. The jet after striking the plate, comes out with the same velocity if the plate is smooth and there is no loss of energy due to impact of the jet, in the tangential direction of the curved plate. The velocity at outlet of the plate can be resolved into two components one in the direction of jet and other perpendicular to the direction of the jet.

Component of velocity in the direction of jet $= -V\cos\theta$



(-ve sign is taken as the velocity at outlet is in the opposite direction of the jet of water coming out from nozzle)

Component of velocity perpendicular to the jet $= V\sin\theta$

Force exerted by the jet in the direction of jet, $F_x =$ mass per sec $\times [V_{1x} - V_{2x}]$

where $V_{1x} =$ initial velocity in the direction of jet $= V$

$V_{2x} =$ final velocity in the direction of jet $= -V\cos\theta$

$$F_x = \rho a V[V - (-V\cos\theta)] = \rho a V[V + V\cos\theta]$$
$$= \rho a V^2[1 + \cos\theta]$$

similarly, $F_y =$ mass per sec $\times [V_{1y} - V_{2y}]$

where, $V_{1y} =$ initial velocity in the direction of $y = 0$

$V_{2y} =$ final velocity in the direction of $y = V\sin\theta$

$$F_y = \rho a V[0 - V\sin\theta] = -\rho a V^2\sin\theta$$

-ve sign indicates, force is acting in the downward direction.

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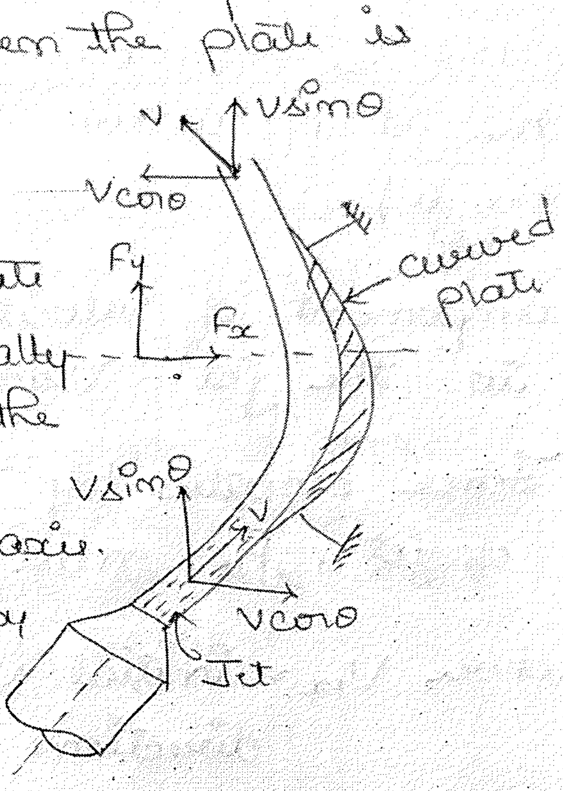
(B) Jet strikes the curved plate at one end tangentially when the plate is symmmetrical.

Let the jet strikes the curved fixed plate at one end tangentially as shown in fig. Let the curved plate is symmmetrical about x-axis. Then the angle made by the tangents at the two ends of the plate will be same.



Let V = velocity of jet of water
θ = angle made by jet with x-axis at inlet tip of the curved plate

If the plate is smooth and loss of energy due to impact is zero, then the velocity of water at the outlet tip of the curved plate will be equal to V. The forces excerted by the jet of water in the directions of x and y are

$$F_x = (\text{mass/sec}) \times [V_{1x} - V_{2x}]$$
$$= \rho a V [V\cos\theta - (-V\cos\theta)]$$
$$= \rho a V [V\cos\theta + V\cos\theta]$$
$$= 2\rho a V^2 \cos\theta$$

$$F_y = \rho a v [V_{1y} - V_{2y}]$$
$$= \rho a v [V \sin\theta - V \sin\theta] = 0$$

(c) Jet strikes the curved plate at one end tangentially when the plate is unsymmmetrical.

When the curved plate is unsymmmetrical about x-axis, then angle made by the tangents drawn at the inlet & outlet tips of the plate with x-axis will be different,

Let θ = angle made by tangent at inlet tip with x-axis

ϕ = angle made by tangent at outlet tip with x-axis.

The Two components of the velocity at inlet are

$V_{1x} = V\cos\theta$ and $V_{1y} = V\sin\theta$

The two components of the velocity at outlet are

$V_{2x} = -V\cos\phi$ and $V_{2y} = V\sin\phi$

∴ The forces excited by the jet of water in the directions of x and y are

$F_x = \rho a v [V_{1x} - V_{2x}] = \rho a v [V\cos\theta - (-V\cos\phi)]$

$= \rho a v [V\cos\theta + V\cos\phi] = \rho a v^2 [\cos\theta + \cos\phi]$

$F_y = \rho a v [V_{1y} - V_{2y}] = \rho a v [V\sin\theta - V\sin\phi]$

$= \rho a v^2 [\sin\theta - \sin\phi]$

Problems

(1) Find the force exerted by a jet of water of diameter 75mm on a stationary flat plate, when the jet strikes the plate normally with velocity of 20 m/s.

⇒ diameter of jet, $d = 75mm = 0.075m$

area $= a = \frac{\pi d^2}{4} = \frac{\pi}{4}(0.075)^2 = 0.004417\ m^2$

velocity of jet, $V = 20m/s$

$F = \rho a v^2$ where $\rho = 1000\ kg/m^3$

$F = 1000 \times 0.004417 \times 20^2\ N$

$\boxed{F = 1766.8\ N}$

(2) Water is flowing through a pipe at the end of which a nozzle is fitted. The diameter of the nozzle is 100mm and the head of water at the centre nozzle is 100mm. Find the force exerted

by the jet of water on a fixed vertical plate. The co-efficient of velocity is given as 0.95.

⇒ diameter of nozzle, $d = 100mm = 0.1m$

Head of water, $H = 100m$

Co-efficient of velocity, $C_v = 0.95$

area of nozzle, $a = \frac{\pi}{4}(0.1)^2 = 0.007854 m^2$

$$V_{th} = \sqrt{2gH} = \sqrt{2 \times 9.81 \times 100} = 44.294 \ m/s$$

$$C_v = \frac{\text{actual velocity}}{\text{Theoretical velocity}}$$

$$\therefore V = C_v \times V_{th}$$

$$= 0.95 \times 44.294$$

$$= 42.08 \ m/s$$

$$F = \rho a v^2 = 1000 \times 0.007854 \times 42.08^2$$

$$\boxed{F = 13.9 \ kN}$$

(3) A jet of water of diameter 75mm moving with a velocity of 25m/s strikes a fixed plate in such a way that the angle b/w the jet and plate is 60°. Find the force exerted by the jet on the plate (i) in the direction normal to the plate (ii) in the direction of the jet.

⇒ diameter of Jet, $d = 75mm = 0.075m$

area, $a = \frac{\pi d^2}{4} = \frac{\pi}{4}(0.075)^2 = 0.004417 m^2$

Velocity of Jet, $V = 25 m/s$

angle b/w jet and plate $\theta = 60°$

(i) $F_n = \rho a V^2 \sin\theta$

$= 1000 \times 0.004417 \times 25^2 \times \sin 60°$

$\boxed{F_n = 2390.7 N}$

(ii) $F_x = \rho a V^2 \sin^2\theta$

$= 1000 \times 0.004417 \times 25^2 \times \sin^2 60$

$\boxed{F_x = 2070.4 N}$

(4) A jet of water of diameter 50mm strikes a fixed plate in such a way that the angle b/w the plate and the jet is 30°. The force exerted in the direction of the jet is 1471.5 N. Determine the rate of flow of water.

⇒ $d = 50mm = 0.05m$

$a = \frac{\pi}{4}(0.05)^2 = 0.001963 m^2$

$\theta = 30°$

$F_x = 1471.5 N$

$F_x = \rho a V^2 \sin^2\theta$

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$$1471.5 = 1000 \times 0.001963 \times V^2 \times \sin^2 30^\circ$$

$$= 0.05V^2$$

$$V^2 = \frac{150}{0.05} = 3000$$

$$V = 54.77 \text{ m/s}$$

$$Q = A \times V$$

$$= 0.001963 \times 54.77$$

$$= \underline{107.5 \text{ l/s}}$$

(5) A jet of water of diameter 50mm moving with a velocity of 40m/s, strikes a curved fixed symmetrical plate at the centre. Find the force exerted by the jet of water in the direction of the jet, if the jet is deflected through an angle of 120° at the outlet of the curved plate.

⇒ $d = 50\text{mm} = 0.05\text{m}$

$$a = \frac{\pi}{4}(0.05)^2 = 0.001963\text{m}^2$$

$$V = 40\text{m/s}$$

Angle of deflection = 120°

from eqⁿ, angle of deflection = 180° − θ

$$180^\circ - \theta = 120^\circ \quad \text{or}$$

$$\theta = 180 - 120$$

$$\theta = 60^\circ$$

$$F_x = \rho a V^2 [1 + \cos\theta]$$

$$= 1000 \times 0.001963 \times 40^2 \times [1 + \cos 60]$$

$$= 4711.15\text{N}$$

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MODULE-5

Reaction turbines and Pumps: Radial flow reaction turbines (i) Francis turbine: Descriptions, working proportions and design, Numerical problems (ii) Kaplan turbine: Descriptions, working proportions and design, Numerical problems, Draft tube theory and unit quantities (No problems)

Centrifugal pumps: Components and working of centrifugal pumps. Types of Centrifugal pumps, Work done by the impeller, Heads and efficiencies, Minimum starting speed of centrifugal pump, Multi-stage pumps. Numerical problems.

Radial flow reaction turbines

Radial flow Turbines are those turbines in which the water flows in the radial direction. The water may flow radially from outwards to inwards or from inwards to outwards. If the water flows from outwards to inwards through the runner, the turbine is

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known as inward radial flow turbine. And if the water flows from inwards to outwards, the turbine is known as outward radial flow turbine.

Reaction turbine means that the water at the inlet of the turbine possesses kinetic energy as well as pressure energy.

Main Parts of a radial flow reaction Turbine

The main parts of a radial flow reaction turbine are

(1) Casing
(2) Guide mechanism
(3) Runner
(4) Draft tube

Casing: In case of reaction turbine, casing and runner are always full of water. The water from the penstocks enters the casing which is of spiral shape in which area of cross-section of the casing goes on decreasing gradually. The casing completely surrounds the runner of the turbine. The casing is made of spiral shape, so that the water may enter the runner at constant velocity throughout the circumference of the runner. The casing is made of concrete, cast steel or plate steel.

Guide Mechanism: It consists of a stationary circular wheel all around the runner of the turbine. The stationary guide vanes are fixed on the guide mechanism. The guide vanes allow the water to strike the vanes fixed on the runner without shock at inlet. Also by a suitable arrangement, the width b/w two adjacent vanes of guide mechanism can be altered so that the amount of water striking the runner can be varied

Runner: It is a circular wheel on which a series of radial curved vanes are fixed The surface of the vanes are made very smooth. The radial curved vanes are so shaped that the water enters and leaves the runner without shock. The runners are made of cast steel, cast iron or stainless steel. They are keyed to the shaft.

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Draft tube: The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure. The water at exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of the turbine to the tail race. This tube of increasing area is called draft tube.

FRANCIS TURBINE

The inward flow reaction turbine having radial discharge at outlet is known as Francis turbine.

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Fig shows inward radial flow turbine, in which case the water from the casing enters the stationary guiding wheel. The guiding wheel consists of guide vanes which direct the water to. enter the runner which consists of moving vanes. The water flows over the moving vanes in the inward radial direction and is discharged at the inner diameter of the runner. The outer diameter of the runner is the inlet and the inner diameter is the outlet.

From the force exerted on the vanes, the work done by water, the horse power given by the water to the vanes and efficiency of the vanes can be obtained. From the velocity triangles, the work done by the water on the runners, horse power and efficiency of the turbine can be obtained.

The work done per second on the runner by water is given by

$$= \rho a v_1 [V_{w_1} u_1 \pm V_{w_2} u_2]$$

$$= \rho Q [V_{w_1} u_1 \pm V_{w_2} u_2] \text{ ——— } ① \quad [a v_1 = Q$$

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The eq^n ① also represents the energy transfer per second to the runner

where, V_{w_1} = velocity of whirl at inlet

V_{w_2} = velocity of whirl at outlet

u_1 = Tangential velocity of wheel at inlet

$= \frac{\pi D_1 \times N}{60}$, where D_1 = outer dia of runner

u_2 = Tangential velocity of wheel at outlet

$= \frac{\pi D_2 \times N}{60}$, where D_2 = inner dia. of runner

N = speed of the turbine in rpm

The work done per second per unit weight of water per second

$$= \frac{\text{work done per second}}{\text{weight of water striking per second}}$$

$$= \frac{\rho Q \left[V_{w_1} u_1 \pm V_{w_2} u_2 \right]}{\rho Q \times g}$$

$$= \frac{1}{g} \left[V_{w_1} u_1 \pm V_{w_2} u_2 \right]$$

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This eq^n is known as Euler's eq^n of hydrodynamics machines. +ve sign is taken if angle β is an acute angle. If β is an obtuse angle then -ve sign is taken. If $\beta = 90°$, then $V_{w_2} = 0$ and work done per second per unit weight of water strikings become as,

$$= \frac{1}{g} V_{w_1} u_1$$

Hydraulic efficiency is obtained as

$$\eta_h = \frac{RP}{WP} = \frac{\frac{W}{1000g}\left[V_{w_1}u_1 \pm V_{w_2}u_2\right]}{\frac{W \times H}{1000}}$$

$$= \frac{\left(V_{w_1}u_1 \pm V_{w_2}u_2\right)}{gH}$$

where RP = Runner power

WP = Water power

If the discharge is radial at outlet, then $V_{w_1} = 0$

$$\boxed{\eta_h = \frac{V_{w_1}u_1}{gH}}$$

(1) A Francis turbine with an overall efficiency of 75% is required to produce 148.25 KW power. It is working under a head of 7.62m. The peripheral velocity = $0.26\sqrt{2gH}$ and the radial velocity of flow at inlet is $0.96\sqrt{2gH}$. The wheel runs at 150 rpm and the hydraulic losses in the turbine are 22% of the available energy. Assuming radial discharge, determine (i) the guide blade angle at inlet
(ii) The wheel vane angle at inlet
(iii) diameter of the wheel at inlet.
(iv) width of the wheel at inlet.

⇒ Overall efficiency, $\eta_o = 75\% = 0.75$

Power produced, SP = 148.25 KW

Head, H = 7.62m

peripheral velocity, $u_1 = 0.26\sqrt{2gH}$

$$= 0.26\times\sqrt{2\times9.81\times7.62}$$

$$= 3.179 \text{ m/s}$$

velocity of flow at inlet, $V_{f_1} = 0.96\sqrt{2gH}$

$$= 0.96\times\sqrt{2\times9.81\times7.62}$$

$$= 11.738 \text{ m/s}$$

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Speed, N = 150 rpm

Hydraulic losses = 22% of available energy

discharge at outlet = radial

$V_{w_2} = 0$ and $V_{f_2} = V_2$

Hydraulic efficiency is given as,

$$\eta_h = \frac{\text{Total head at inlet} - \text{Hydraulic loss}}{\text{Head at inlet}}$$

$$= \frac{H - 0.22H}{H} = \frac{0.78H}{H} = 0.78$$

But, $\eta_h = \dfrac{V_{w_1} u_1}{gH}$

$$\frac{V_{w_1} u_1}{gH} = 0.78$$

$$V_{w_1} = \frac{0.78 \times g \times H}{u_1}$$

$$= \frac{0.78 \times 9.81 \times 7.62}{3.179} = 18.34 \text{ m/s}$$

(i) The guide blade angle, i.e α.
from inlet velocity triangle

$$\tan\alpha = \frac{V_{f_1}}{V_{w_1}} = \frac{11.738}{18.34} = 0.64$$

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$\alpha = \tan^{-1} 0.64 = 32.619^\circ$ or $32^\circ 37'$

(ii) The wheel vane angle at inlet i.e θ

$$\tan\theta = \frac{V_{f_1}}{V_{w_1} - u_1} = \frac{11.738}{18.34 - 3.179} = 0.774$$

$$\theta = \tan^{-1} 0.774$$
$$= 37.74 \text{ or } 37^\circ 44.4'$$

(iii) Diameter of wheel at inlet (D_1)

$$u_1 = \frac{\pi D_1 N}{60}$$

$$D_1 = \frac{60 \times u_1}{\pi \times N} = \frac{60 \times 3.179}{\pi \times 50} = 0.4047 m$$

(iv) Width of the wheel at inlet (B_1)

$$\eta_o = \frac{SP}{WP} = \frac{148.25}{WP}$$

But
$$WP = \frac{WH}{1000} = \frac{\rho \times g \times Q \times H}{1000}$$
$$= \frac{1000 \times 9.81 \times Q \times 7.62}{1000}$$

$$\eta_o = \frac{148.25}{\frac{1000 \times 9.81 \times Q \times 7.62}{1000}}$$

$$Q = \frac{148.25 \times 1000}{1000 \times 9.81 \times 7.62 \times \eta_0}$$

$$Q = 2.644 \ m^3/s$$

$$Q = \pi D_1 \times B_1 \times V_{f1}$$

$$2.644 = \pi \times 0.4047 \times B_1 \times 11.738$$

$$B_1 = \frac{2.644}{\pi \times 0.4047 \times 11.738} = \underline{\underline{0.177 m}}$$

(2) The following data is given for a Francis turbine. Net head $H = 60m$, speed $N = 700$ rpm, shaft power $= 294.3$ kW $\eta_0 = 84\%$, $\eta_h = 93\%$, flow ratio $= 0.20$ breadth ratio $n = 0.1$, Outer diameter of the runner $= 2 \times$ inner dia of runner. The thickness of vanes occupy 5% of circumferential area of the runner, velocity of flow is constant at inlet and outlet and discharge is radial at outlet. Determine

(i) Guide blade angle

(ii) Runner vane angles at inlet & outlet

(iii) diameters of runner at inlet & outlet

(iv) Width of wheel at inlet.

⟹ Net head, $H = 60m$

Speed, $N = 700$ rpm

Shaft power $= 294.3$ KW

Overall efficiency, $\eta_o = 84\% = 0.84$

Hydraulic efficiency, $\eta_h = 93\% = 0.93$

Flow ratio, $\frac{V_{f_1}}{\sqrt{2gH}} = 0.2$

$$V_{f_1} = 0.2 \times \sqrt{2gH}$$
$$= 0.2 \times \sqrt{2 \times 9.81 \times 60}$$
$$= 6.862 \text{ m/s}$$

Breadth ratio, $\frac{B_1}{D_1} = 0.1$

Outer diameter, $D_1 = 2 \times$ inner dia
$= 2 \times D_2$

velocity of flow, $V_{f_1} = V_{f_2} = 6.862$ m/s

Thickness of vanes $= 5\%$ of circumferential area of runner

∴ Actual area of flow $= 0.95 \pi D_1 \times B_1$

Discharge at outlet = radial

$V_{w_2} = 0$ and $V_{f_2} = V_2$

$$\eta_o = \frac{SP}{WP}$$

$$0.84 = \frac{294.3}{WP}$$

$WP = \frac{294.3}{0.84} = 350.357 \, KW$

But , $WP = \frac{WH}{1000} = \frac{\rho \times g \times Q \times H}{1000}$

$350.357 = \frac{1000 \times 9.81 \times Q \times 60}{1000}$

$Q = 0.5952 \, m^3/s$

Q = actual area of flow × velocity of flow

$= 0.95 \pi D_1 \times B_1 \times V_{f1}$

$= 0.95 \times \pi \times D_1 \times 0.1 D_1 \times V_{f2}$

$(\because B_1 = 0.1 D_1)$

$0.5952 = 0.95 \times \pi \times D_1 \times 0.1 \times D_1 \times 6.862$

$0.5952 = 2.048 D_1^2$

$D_1 = \sqrt{\frac{0.5952}{2.048}}$

$\boxed{D_1 = 0.54 m}$

But $\frac{B_1}{D_1} = 0.1$

$B_1 = 0.1 \times D_1$

$\boxed{B_1 = 0.054 m}$

KAPLAN TURBINE

If the water flows parallel to the axis of the rotation of the shaft, the turbine is known as axial flow turbine. If the head at the inlet of the turbine is the sum of pressure energy & kinetic energy & during the flow of water through runner a part of pressure energy is converted into kinetic energy, the turbine is known as reaction turbine.

For the axial flow reaction turbine, the shaft of the turbine is vertical. The lower end of the shaft is made larger which is known as 'hub' or 'boss'. The vanes are fixed on the hub and hence hub acts as a runner for axial flow reaction turbine.

The important types of axial flow reaction turbines are:

(1) Propeller Turbine
(2) Kaplan Turbine

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When the vanes are fixed to the hub and they are not adjustable, the turbine is known as propeller turbine.

But if the vanes on the hub are adjustable, the turbine is known as a Kaplan turbine.

The main parts of a Kaplan turbine are

(1) Scroll casing
(2) Guide vanes mechanism
(3) Hub with vanes or runner of the turbine
(4) Draft tube.

The water from penstock enters the scroll casing and then moves to the guide vanes. From the guide vanes, the water turns through 90° and flows axially through the runner. The discharge through the runner is obtained as

$$Q = \frac{\pi}{4}\left(D_o^2 - D_b^3\right) \times V_{f_1}$$

D_o → outer diameter of the runner

D_b → diameter of hub

V_{f_1} → velocity of flow at inlet

(1) A Kaplan turbine working under a head of 20m develops 11772 kW shaft power. The outer diameter of the runner is 3.5m and hub diameter is 1.75m. The guide blade angle at the extreme edge of the runner is 35°. The hydraulic and overall efficiencies of the turbines are 88% and 84% respectively. If the velocity of whirl is zero at outlet, determine

(i) Runner vane angles at inlet & outlet at the extreme edge of the runner.

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(ii) Speed of the turbine

⇒ Head, $H = 20m$

Shaft power, $SP = 11772 kW$

Outer dia. of runner = $D_o = 3.5m$

Hub diameter, $D_b = 1.75m$

$\alpha = 35°$

$\eta_h = 88\%$

$\eta_o = 84\%$

$$\eta_o = \frac{SP}{WP}$$

$$WP = \frac{WP}{1000} = \frac{\rho g QH}{1000}$$

$$0.84 = \frac{11772}{\frac{\rho g QH}{1000}}$$

$$= \frac{11772 \times 1000}{1000 \times 9.81 \times Q \times 20}$$

$$Q = 71.428 m^3/s$$

$$Q = \frac{\pi}{4}(D_o^2 - D_b^2) \times V_{f_1}$$

$$71.428 = \frac{\pi}{4}(12.25 - 3.0625) V_{f_1}$$

$$V_{f_1} = 9.9 m/s$$

From inlet velocity triangle,

$$\text{Tan}\,\alpha = \frac{V_{f_2}}{V_{w_1}}$$

$$V_{w_1} = \frac{V_{f_1}}{\text{Tan}\,\alpha} = \frac{9.9}{\text{Tan}\,35} = 14.14\,m/s$$

$$\eta_h = \frac{V_{w_1} u_1}{gH}$$

$u_1 = 12.21\,m/s$

(i) $$\text{Tan}\,\theta = \frac{V_{f_1}}{V_{w_1} - u_1} = \frac{9.9}{(14.14 - 12.21)} = 5.13$$

$\theta = 78^\circ 58'$

$u_1 = u_2 = 12.21\,m/s$

$V_{f_1} = V_{f_2} = 9.9\,m/s$

$$\text{Tan}\,\phi = \frac{V_{f_2}}{u_2} = \frac{9.9}{12.21} = 0.811$$

$\phi = 39^\circ 2'$

(ii) $$u_1 = u_2 = \frac{\pi D_o N}{60}$$

$N = 66.63$ rpm

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17CV43

Fourth Semester B.E. Degree Examination, June/July 2019
Applied Hydraulics

Time: 3 hrs. Max. Marks: 100

Note: 1. *Answer any FIVE full questions, choosing ONE full question from each module.*
2. *Missing data may suitably be assumed.*

Module-1

1 a. Explain Dimensionally Homogeneous equation. Give any two examples. **(10 Marks)**

b. Using Buckingham's π – theorem, show that the velocity through a circular orifice is given by $V = \sqrt{2gH}\ \phi\left[\frac{D}{H}, \frac{\mu}{\rho V H}\right]$, where H is head causing flow, μ is coefficient viscosity, ρ = mass density and g = gravitational acceleration. **(10 Marks)**

OR

2 a. Derive an expression for kinematic and dynamic similarities. **(04 Marks)**

b. In the model test of a spillway the discharge and velocity of flow over the model were $2m^3/s$ and 1.53 m/s respectively. Calculate the velocity and discharge over the prototype which is 36 times the model size. **(08 Marks)**

c. A solid cylinder 2m in diameter and 2m high is floating in water with its axis vertical. If the specific gravity of the material of cylinder is 0.65, find its metacentric height. State also whether the equilibrium is stable or unstable. **(08 Marks)**

Module-2

3 a. Explain various types of flows in channel. **(10 Marks)**

b. A canal of trapezoidal section has bed width of 8m and bed slope of 1 in 4000. If the depth of flow is 2.4m and side slopes of the channel are 1H to 3V, then determine the average velocity and the discharge carried by the channel. Also compute the average shear stress at the channel boundary. Take C = 56. **(10 Marks)**

OR

4 a. Obtain the conditions of most economical trapezoidal section in which side slope is constant. **(10 Marks)**

b. A 8m wide channel conveys $15m^3/s$ of water at a depth of 1.2m. Obtain the following :

i) Specific energy of the flowing water.
ii) Critical depth, Critical velocity and minimum specific energy.
iii) Froude number and state whether flow is subcritical or supercritical. **(10 Marks)**

Module-3

5 a. Derive an expression for loss of energy head for hydraulic jump. **(10 Marks)**

b. In a rectangular channel of 0.5m width, a hydraulic jump occurs at a point where depth of water flow is 0.15m and Froude number is 2.5 obtain the following :
i) Sp. Energy ii) Critical and subsequent depths iii) Loss of head and iv) Energy dissipated. **(10 Marks)**

OR

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6 a. Derive an expression for length of Back water curve. **(10 Marks)**

b. In a rectangular channel of width 24m and depth of flow 6m, the rate of flow of water is 86.4 m^3/S. If the bed slope of the channel is 1 in 4000 then find the slope of the free surface of water. Take C = 60. **(10 Marks)**

Module-4

7 a. Derive an expression for impulse momentum equation. **(05 Marks)**

b. Derive an expression for thrust exerted by the jet strikes a stationary curved vane at one end tangentially when the vane is symmetrical. **(07 Marks)**

c. A jet of water from a nozzle is deflected through 60^0 from its original direction by curved vane which enters tangentially without shock with a velocity of 30m/s and leaves with a mean velocity of 25m/s. If the mass issued from nozzle per second is 0.8 kg/s, calculate the magnitude and direction of the resultant force on the vane, if the vane is stationary. **(08 Marks)**

OR

8 a. Explain classification and efficiencies of turbines. **(10 Marks)**

b. A pelton wheel is to be designed for the following specifications :
Shaft power = 11,772 kW ; Head = 380m ; Speed = 750 r.p.m ; Overall efficiency = 86%
Jet diameter is not to exceed one – sixth of the wheel diameter. Determine
i) Wheel diameter ii) No. of jets required iii) Diameter of the jet.
Take $K_{v_1} = 0.985$ and $K_{u_1} = 0.45$. **(10 Marks)**

Module-5

9 a. With the help of neat sketches, explain Franci's inward flow reaction turbine. **(10 Marks)**

b. Calculate the diameter and speed of the runner of a Kaplan turbine developing 6000 kW under an effective head of 5m. Overall efficiency of the turbine is 90%. The diameter of boss is 0.4 times the external diameter of the runner. The turbine speed ratio is 2.0 and flow ratio 0.6. What is the specific speed of the turbine? **(10 Marks)**

OR

10 a. Explain with neat sketches, components and working of a centrifugal pump. **(10 Marks)**

b. A centrifugal pump impeller runs at 80 r.p.m and has outlet vane angle of 60°. The velocit of flow is 2.5m/s throughout and diameter of impeller at exit is twice that at inlet. If the manometric head is 20m and the manometric efficiency is 75%, determine
i) The diameter of impeller at the exit ii) Inlet vane angle. **(10 Marks)**

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17CV43

Fourth Semester B.E. Degree Examination, Aug./Sept.2020
Applied Hydraulics

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. Assume any missing data if any suitably.

Module-1

1 a. Differentiate between dimensionally homogeneous and non-homogeneous with an example each. **(06 Marks)**

b. What is dimensional analysis? Mention its uses. **(06 Marks)**

c. Capillary rise 'h' depends upon density 'ρ', acceleration due to gravity, 'g', surface tension, 'σ' and radius of tube, 'r'. Show by Buckingham π – theorem that,

$$\frac{h}{r} = \phi\left[\frac{\sigma}{\rho g r^2}\right]$$ **(08 Marks)**

OR

2 a. Explain Reynold's model law and give the areas where it is applied. **(06 Marks)**

b. What are distorted and undistorted models? **(04 Marks)**

c. The discharge and velocity of flow over the model of a spillway of a dam were measured to be 2.0 m^3/s and 2.5 m/s respectively. If the model is built to a scale of 1:36, compute the velocity and discharge over its prototype. **(10 Marks)**

Module-2

3 a. Derive Chezy's equation for uniform flow in open channel and thereby deduce Manning's formula for velocity in open channel. **(08 Marks)**

b. A circular open channel laid to a gradient of 1:9000 carries a discharge of 0.40 m^3/s. If the depth of flow is 1.25 times the radius of channel, find the diameter of the channel. Assume rugosity coefficient for channel surface as 0.015. **(12 Marks)**

OR

4 a. How do you define specific energy of a flowing? Draw specific energy curve and explain various parameters. **(06 Marks)**

b. Enumerate the characteristics of critical flow through open channels. **(04 Marks)**

c. The discharge in a 4.0 m wide rectangular channel at 1.0m depth of flow is 4.0 m^3/s. Compute (i) Specific energy for 1.0m depth of flow (ii) Critical depth (iii) Alternate depth to 1.0m. **(10 Marks)**

Module-3

5 a. Define hydraulic jump in an open channel flow. Give its applications. **(06 Marks)**

b. Prove that the critical depth (y_c) and the alternate depths y_1 and y_2 are related by the expression, $y_c^3 = \frac{2y_1^2y_2^2}{(y_1+y_2)}$, in a rectangular open channel. **(06 Marks)**

c. In a rectangular channel of width 6.0m, the sluice gate discharges with a velocity of 5.0 m/s at a depth of 0.40m. Determine whether a hydraulic jump will occur. Also find (i) Jump height (ii) Energy lost per kg of water and (iii) Power lost in the hydraulic jump. **(08 Marks)**

OR

6 a. Explain classification of surface profiles with neat sketches. **(10 Marks)**

b. A rectangular channel 10m wide carries a discharge of 40 m^3/s. If at a section in this channel, the depth of flow is 1.50m, how far upstream or downstream from this section will the depth be 2.0m. Take channel bedslope as 0.00009 and Manning's N = 0.017. **(10 Marks)**

Module-4

7 a. Derive an expression for the force exerted by a jet striking a moving symmetrical curved vane striking at the center and hence how that the maximum efficiency of this jet-vane system is limited to 16/27. **(10 Marks)**

b. A jet water moving at 20 m/s impinges on a symmetrical curved vane so shaped to deflect the jet through 120°. If the vane is moving at 5.0 m/s, find the angle of jet so that there is no shock at the inlet. Also determine the absolute velocity at the exit in magnitude and direction and the work done per unit weight of water. **(10 Marks)**

OR

8 a. Draw a general layout of a hydro-electric power plant and give the function of each of the components in brief. **(10 Marks)**

b. A Pelton wheel running at a speed of 600 rpm under a head of 820 m develops 13200 kW power. If the coefficient of jet $C_v = 0.98$, Speed ratio, $\phi = 0.46$ and jet diameter is 1/16 of wheel diameter, calculate (i) Pitch circle diameter (ii) Diameter of the jet (iii) Quantity of water supplied to the wheel and (iv) the number of jets required. Assume overall efficiency as 85%. **(10 Marks)**

Module-5

9 a. Draw a neat sketch of a Francis turbine and explain its components. **(04 Marks)**

b. What is a draft tube? Explain its function in a reaction turbine. **(06 Marks)**

c. A Kaplan turbine runner is to be designed to develop 9100 kW power. The net available head is 5.6m. If the speed ratio = 2, flow ratio = 0.68, overall efficiency = 86% and the diameter of boss is equal to $1/3^{rd}$ the diameter of runner, find the diameter of runner, the speed and specific speed of turbine. **(10 Marks)**

OR

10 a. Explain various heads and efficiencies of centrifugal pumps. **(10 Marks)**

b. A centrifugal pump with radial inflow delivers 0.08 cumecs of water against a total head of 40m. If the outer diameter of the impeller is 30cm and its width at the outer periphery is 1.25 cm, find the blade angle at exit. The speed of the pump is 1500 rpm and its manometric efficiency is 80%. **(10 Marks)**

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Fourth Semester B.E. Degree Examination, Dec.2019/Jan.2020

Applied Hydraulics

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define the terms: (i) Model (ii) Prototype (iii) Model analysis (iv) Hydraulic similitude **(06 Marks)**

b. In 1 in 40 model of spillway the velocity and discharge are 2m/s and 2.5 m^3/s. Find the corresponding velocity and discharge in the prototype. **(04 Marks)**

c. Using Buckingham's π - theorem, derive the following relationship $R = \rho V^2 D^2 \phi\left(\frac{\mu}{\rho VD}, \frac{H}{D}\right)$ where R = resistance, ρ = density, V = velocity of flow, D = diameter, μ = viscosity and H = height. **(10 Marks)**

OR

2 a. Explain the types of similarities in model analysis. **(06 Marks)**

b. A pipe of diameter 1.8 m is required to transport an oil of specific gravity 0.8 and viscosity 0.04 poise at the rate of 4 m^3/s. Tests were conducted on a 20 cm diameter pipe using water at 20°C. Find the velocity and rate of flow in model, viscosity of water at 20°C is 0.01 poise. **(08 Marks)**

c. Explain the experimental method of determination of meta-centric height. **(06 Marks)**

Module-2

3 a. Distinguish between pipe flow and open channel flow. **(04 Marks)**

b. Derive Chezy's equation for uniform flow in open channel with usual notations. **(08 Marks)**

c. A trapezoidal channel with side slopes 3H:2V has to be designed to carry 10 m^3/s at velocity of 1.5 m/s, so that the amount of concrete lining for the bed and sides is minimum. Find: (i) The wetted perimeter (ii) Slope of bed if Manning's N = 0.014 **(08 Marks)**

OR

4 a. For most economical trapezoidal section show that half of the top width is equal to one of the side slope length. **(06 Marks)**

b. Explain with neat sketch the specific energy curve. **(06 Marks)**

c. A discharge of 18 m^3/s flows through a rectangular channel 6m wide at a depth of 1.6 m. Find: (i) specific energy (ii) critical depth (iii) critical velocity (iv) value of minimum specific energy. **(08 Marks)**

Module-3

5 a. Define the term hydraulic jump. Derive an expression for a hydraulic jump in a horizontal rectangular channel. **(10 Marks)**

b. Find the slope of the free water surface in a rectangular channel of width 20 m having depth of flow 5m. The discharge through the channel is 50 m^3/s. The bed of the channel is having a slope of 1 in 4000. Take the value of Chezy's constant C = 60. **(10 Marks)**

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OR

6 a. Explain the following slope profiler, (i) Critical slope (ii) Mild slope (iii) Steep slope and also draw profile of M_1, M_2 and M_3. **(10 Marks)**

b. A sluice gate discharges water into a horizontal channel with a velocity of 5m/s and depth of flow is 0.4 m. The width of the channel is 6m. Determine whether a hydraulic jump will occur, and if so find its height and loss of energy per kg of water. Also determine the power lost in the hydraulic jump. **(10 Marks)**

Module-4

7 a. Find an expression for the efficiency of a series of moving curved vanes when a jet of water strokes the vanes at one of the tips. Prove that maximum efficiency is 50% when $u > v$. **(10 Marks)**

b. A pelton wheel has to develop 13200 KW under a net head of 820 m while running at a speed of 600 rpm. If the coefficient of jet $C_V = 0.98$, speed ratio $\phi = 0.46$ and jet diameter is $\frac{1}{16}$ of wheel diameter, calculate (i) pitch circle diameter (ii) the diameter of the jet (iii) quantity of water supplied to the wheel (iv) Number of jets required. Assume overall efficiency as 85%. **(10 Marks)**

OR

8 a. Draw a neat sketch of a layout of hydroelectric power plant and explain the functions of each component. Also define different heads. **(10 Marks)**

b. A jet of water having a velocity of 35 m/s impinges on a series of vanes moving with a velocity of 20 m/s. The jet makes an angle of 30° to the direction of vanes when entering and leaves at an angle of 120°. Draw the triangles of velocities at inlet and outlet and find,

(i) The angles of vanes tips so that water enters and leaves without shock.
(ii) The work done per unit weight of water entering the vanes
(iii) Efficiency. **(10 Marks)**

Module-5

9 a. What is a draft tube? What are the functions of draft tube? **(04 Marks)**

b. Derive the expression for minimum starting speed of a centrifugal pump. **(06 Marks)**

c. A Kaplan turbine develops 24647.6 KW power at an average head of 39 m. Assuming the speed ratio of 2, flow ratio of 0.6, diameter of boss equals to 0.35 times the diameter of runner and an overall efficiency of 90%, calculate the diameter, speed and specific speed of the turbine. **(10 Marks)**

OR

10 a. Explain manometric efficiency, mechanical efficiency and overall efficiency of a centrifugal pump. **(06 Marks)**

b. Define unit head, unit discharge and unit power. **(04 Marks)**

c. A centrifugal pump is to deliver 0.12 m^3/s at a speed of 1450 rpm against a head of 25 m. The impeller diameter is 250 mm, width at outlet is 50 mm. The manometric efficiency is 75%. Determine the vane angles at the outer periphery of the impeller. **(10 Marks)**

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CBCS SCHEME

USN

15CV43

Fourth Semester B.E. Degree Examination, June/July 2019

Applied Hydraulics

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. State and prove the Buckingham π-Theorem. Also explain its advantages over Rayleigh's method of dimensional analysis. **(05 Marks)**

b. A ship 300m long moves in sea-water, whose density is 1030 kg/m^3. A 1:100 model of this ship is to be tested in a wind tunnel. The velocity of air in the wind tunnel around the model is 30 m/s and the resistance of the model is 60N. Determine the velocity of ship in sea-water and also the resistance of the ship in sea-water. The density of air is given as 1.24 kg/m^3. Take the kinematic viscosity of sea-water and air as 0.012 strokes and 0.018 strokes respectively. **(08 Marks)**

c. Define: Buoyancy, Metacentre Metacentric height. **(03 Marks)**

OR

2 a. Explain the Froude model law. Derive the different scale ratio for Froude model law. **(08 Marks)**

b. Derive on the basis of dimensional analysis suitable parameters to present the thrust developed by a propeller. Assume that the thrust P depends upon the angular velocity W speed of advance V, diameter D, dynamic viscosity μ, mass density ρ, elasticity of the fluid medium which can be denoted by the speed of sound in the medium C. **(08 Marks)**

Module-2

3 a. Prove that for a channel of circular section the depth of flow d = 0.81D for maximum velocity. Where D = Diameter of circular channel, d = depth of flow. **(08 Marks)**

b. The discharge of water through a rectangular channel of which width 8m is 15m^3/s when depth of flow of water is 1.2m. Calculate:
i) Specific energy of the flowing water
ii) Critical depth and critical velocity
iii) Value of maximum specific energy. **(08 Marks)**

OR

4 a. Explain specific energy curve, and thus derive expression for critical depth and critical velocity. **(08 Marks)**

b. An open channel of most economical section, having the form of a half hexagon with horizontal bottom is required to give a maximum discharge of 20.2 m^3/s of water. The slope of the channel bottom is 1 in 2500. Taking Chezy's constant C = 60 in Chezy's equation, determine the dimensions of the cross-section. **(08 Marks)**

Module-3

5 a. Define the term hydraulic jump. Derive an expression for depth of hydraulic jump in terms of u/s Froude's number. **(08 Marks)**

b. Find the slope of the free water surface in a rectangular channel of width 20m having depth of flow 5m. The discharge through the channel is $50m^3/s$. The bed of the channel is having a slope of 1 in 4000. Take the value of Chezy's constant C = 60. **(08 Marks)**

OR

6 a. Derive an expression for the length of Back water curve **(08 Marks)**

b. A sluice gate discharge water in to a horizontal rectangular channel with a velocity of 6m/s and depth of flow is 0.4m. The width of the channel is 8m. Determine whether a hydraulic jump will occur and if so. Find its height and loss of energy per kg of water. Also determine the power lost in the hydraulic jump. **(08 Marks)**

Module-4

7 a. Derive an equation for the force existed by a jet of water on a fixed curved plate in the direction of the jet when the jet strikes at the centre of the plate. Hence show that the force exerted on semi circular plate is two times the force exerted by the jet on an fixed vertical plane plate. **(08 Marks)**

b. A pelton wheel is having a mean bucket diameter of 1m and is running at 999.9 rpm. The net head on the pelton wheel is 699m. If the side clearance angle is 15° and discharges through nozzle is $0.1m^3/s$ find:

i) Power available at the nozzle

ii) Hydraulic efficiency of the turbine. **(08 Marks)**

OR

8 a. A jet of water of diameter 50mm, having a velocity of 20 m/s strikes a curved vane which is moving with a velocity of 10m/s in the direction of the jet. The jet leaves the vane at an angle of 60° to the direction of motion of vane at outlet.

Determine:

i) The force exerted by the jet on the vane in the direction of motion.

ii) Work done per second by the jet. **(08 Marks)**

b. What do you mean by gross had, net Head and efficiency of turbine? Explain the different types of the efficiency of a turbine. **(08 Marks)**

Module-5

9 a. Define draft tube. What are the different types of draft tube? Explain draft tube theory and its efficiency. **(08 Marks)**

b. A centrifugal pump is to discharge $0.118\ m^3/sec$ a speed of 1450 rpm against a head of 25m. The impeller diameter is 250mm. Its width at outlet is 50mm and manometric efficiency is 75%. Determine the vane angle at the outer periphery of the impeller. **(08 Marks)**

OR

10 a. Define specific speed of a centrifugal pump. Derive an expression for the same. **(08 Marks)**

b. A Kaplan turbine develops 24647.6 kW power at an average head of 39m. Assuming a speed ratio of 2. Flow ratio of 0.6, diameter of the boss equal to 0.35 times the diameter of the runner and an overall efficiency of 90%. Calculate the diameter, speed and specific speed of the turbine. **(08 Marks)**

* * * * *

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Assignment

Date	**26**	**05**	**2021**

Assignment No.	I	**Maximum Marks**	10
Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**Scheme**	CBCS – 18
Course Co-ordinator	Ms. Supriya Xavier Lopes		

Note : Answer all the questions.

Q. No.	**Question**	**Marks**	**RBT Level**	**CO**
1	a) Find the expression for the power P, developed by a pump when P depends upon the head H, the discharge Q and specific weight w, of the fluid. b) The efficiency η of a fan depends on the density ρ, the dynamic viscosity μ of the fluid, the angular velocity ω, diameter D of the rotor and the discharge Q. Express η in terms of dimensionless parameters.	2	L3	1
2	a) The pressure difference Δp in a pipe of diameter D and length l due to viscous flow depends on the velocity V, viscosity μ and density ρ. Using Buckingham's π-theorem, obtain an expression for Δp. b) Using Buckingham's π-theorem, show that the discharge Q consumed by an oil ring is given by, where d is the internal diameter of the ring, N is rotational speed, ρ is density, μis viscosity, σ is surface tension and w is the specific weight of oil.	3	L3	1
3	Water is flowing through a pipe of diameter 30cm at a velocity of 4 m/s. Find the velocity of 4m/s. Find the velocity of oil flowing in another pipe of diameter 10cm, if the condition of dynamic similarity is satisfied between the two pipes. The viscosity of water and oil is given as 0.01 poise and 0.025 poise. The sp.gr. of oil = 0.8.	2	L1	1
4	A trapezoidal channel with side slopes of 3Horizontal to 2 Vertical has to be designed to convey 10m^3/s at a velocity of 1.5m/s, so that the amount of concrete lining for the bed and sides is minimum. Find i) the wetted perimeter. ii) slope of the bed if N = 0.014.	1	L3	2
5	The discharge of water through a rectangular channel of width 8m, is 15m^3/s when depth of flow of water is 1.2m. Calculate i) specific energy of the flowing water. ii) Critical depth and Critical velocity. iii) value of min, specific energy.	1	L3	2
6	The specific energy for a 5m wide rectangular channel is to be 4Nm/m. If the rate of flow water through the channel is 20m^3/s, determine the alternate depths of flow.	1	L3	2

Last date for submission	**29**	**05**	**2021**

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

26/5/21

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Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**Scheme**	CBCS – 18
Date	08.06.2021	**CIE No.**	I
Time	9:00 to 10:00 AM	**Max. Marks**	30

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Apply** the dimensional analysis concept for developing mathematical modelling and **compute** the parametric values in prototype by analysing the corresponding model parameters
CO2	**Explain** the concepts of buoyancy and flotation
CO3	**Design** the cross section of channels with uniform flow.
CO4	**Apply** energy concepts in non-uniform flow
CO5	**Apply** the concepts of impulse momentum equation to verify the performance characteristics of turbines
CO6	**Evaluate** the performance characteristics of centrifugal pumps.

Note : Answer any one full question from each Part. Missing data may be assumed suitably.

Q. No.		Question	Marks	RBT Level	CO
		Part A			
1	a)	**State** and **prove** the Buckingham π- Theorem. Also explain its advantages over Rayleigh's method of dimensional analysis.	5	L2	1
	b)	Water is flowing through a pipe of diameter 30cm at a velocity of 4 m/s. **Find** the velocity of oil flowing in another pipe of diameter 10cm, if the condition of dynamic similarity is satisfied between the two pipes. The viscosity of waer and oil is given as 0.01 piose and 0.25 poise. The sp. Gr. Of oil = 0.8.	10	L3	1
	c)	A 1:64 model is constructed of an open channel in concrete which has Manning's N = 0.014. **Find** the value of N for the model.	5	L3	2
2	a)	**Explain** the Froude model Law. Derive the different scale ratio for Froude model law.	5	L2	1
	b)	The pressure difference Δp in a pipe of diameter D and length l due to turbulent flow depends on the velocity V, viscosity μ, density ρ and roughness K. Using Buckingham's π-theorem, **obtain** an expression for Δp.	10	L3	1
	c)	**Explain** the experimental method of determination of meta-centric height.	5	L2	2
		Part B			
3	a)	**Explain** with a neat sketch of specific energy curve. Also derive an expression for critical depth, critical velocity and minimum specific energy.	5	L2	3
	b)	**Prove** that for a channel of circular section the depth of flow d=0.81D for maximum velocity. Where D= diameter of circular channel, d= depth of flow.	5	L3	3
4	a)	**Obtain** the conditions of most economical trapezoidal section in which side slope is constant.	5	L3	3
	b)	**Derive** Chezy's equation for uniform flow in open channel with usual notations.	5	L2	3

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

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Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**CIE No.**	I
Date	8/6/21	**Max. Marks**	30

1) a)	Buckingham π - Theorem – Statement Advantages	2 3
b)	$\rho_2 = 0.8 \times 1000 = 800\ kg/m^3$ $V_2 = 37.5\ m/s$	10
c)	$\frac{V_p}{V_m} = 8$ $N_m = 0.007$	5
2) a)	Froude model law i) Scale ratio for time $(T_r) = \sqrt{L_r}$ ii) " " " acceleration $(a_r) = 1$ iii) " " discharge $(Q_r) = L_r^{2.5}$ iv) " " force $(F_r) = L_r^3$ v) " " pressure intensity $(P_r) = L_r$	5
b)	$\frac{\Delta P}{\rho g} = h_f = \frac{4fLV^2}{D.2g}$	10
c)	Experimental method for meta-centric height	5
3) a)	Specific energy curve	5
b)	Prove $d = 0.81D$	5

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4)a)	Conditions for most economical trapezoidal section 1) $\frac{b+2nd}{2} = d\sqrt{n^2+1}$ 2) $m = d/2$	5
b)	Chezys equation – derive $Q = AC\sqrt{mi}$	5

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Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**Scheme**	CBCS – 18
Date	06.07.2021	**CIE No.**	II
Time	9:00 to 10:00 AM	**Max. Marks**	30

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Apply** the dimensional analysis concept for developing mathematical modelling and **compute** the parametric values in prototype by analysing the corresponding model parameters
CO2	**Explain** the concepts of buoyancy and flotation
CO3	**Design** the cross section of channels with uniform flow.
CO4	**Apply** energy concepts in non-uniform flow
CO5	**Apply** the concepts of impulse momentum equation to verify the performance characteristics of turbines
CO6	**Evaluate** the performance characteristics of centrifugal pumps.

Note :Answer any one full question from each Part. Missing data may be assumed suitably.

Q. No.		**Question**	**Marks**	**RBT Level**	**CO**
		Part A			
1	a)	Derive an expression for loss of energy head for hydraulic jump.	5	L3	4
	b)	Explain back water curve and Afflux.	5	L2	
	c)	A sluice gate discharges water into a horizontal rectangular channel with a velocity of 6m/s and depth of flow is 0.4m. The width of the channel is 8m. Determine whether a hydraulic jump will occur, and if so, find its height and loss of energy per kg of water. Also determine the power lost in the hydraulic jump.	10	L3	
2	a)	Derive an expression for depth of Hydraulic jump.	5	L3	4
	b)	Derive Gradually varied flow.	10	L3	
	c)	A hydraulic jump forms at the downstream end of spillway carrying 17.93 m^3/s discharge. If the depth before jump is 0.8m. Determine the depth after the jump and energy loss.	5	L3	
		Part B			
	a)	Derive an expression for thrust exerted by the jet strikes a stationary curved vane at one end tangentially when the vane is symmetrical.	10	L3	5
4	a)	Derive an expression for thrust exerted by the jet strikes a stationary inclined flat plate.	10	L3	5

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

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Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**CIE No.**	II
Date	6/7/21	**Max. Marks**	30

1) a)	Expression for loss of energy head for hydraulic jump $h_L = \frac{(d_2 - d_1)^3}{4 d_1 d_2}$	5
b)	Back water curve and Afflux – explain	5
c)	$h_L = 1.742\,m$	10
2) a)	Expression for depth of hydraulic jump $d_2 = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2V_1^2 d_1}{g}}$ depth $= (d_2 - d_1)$	5
b)	Gradually varied flow, $\frac{dh}{dx} = \frac{(i_b - i_e)}{\left(1 - \frac{V^2}{gh}\right)}$	10
c)	$h_L = 17.52\,m.$	5
3).	Curved vane, $F_x = 2\rho a V^2 \cos\theta$ $F_y = \rho a V(V\sin\theta - V\sin\theta) = 0$	10
4)	Derive, Inclined flat plate, $F_n = \rho a V(V\sin\theta - 0)$ $F_x = \rho A V^2 \sin^2\theta$ $F_y = \rho A V^2 \sin\theta \cos\theta$	10

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Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**Scheme**	CBCS – 18
Date	03.08.2021	**CIE No.**	III
Time	8:30 to 9:30 AM	**Max. Marks**	30

Course Outcome Statements : After the successful completion of the course, the students will be able to	
CO1	**Apply** the dimensional analysis concept for developing mathematical modelling and **compute** the parametric values in prototype by analysing the corresponding model parameters
CO2	**Explain** the concepts of buoyancy and flotation
CO3	**Design** the cross section of channels with uniform flow.
CO4	**Apply** energy concepts in non-uniform flow
CO5	**Apply** the concepts of impulse momentum equation to verify the performance characteristics of turbines
CO6	**Evaluate** the performance characteristics of centrifugal pumps.

Note : Answer any one full question from each Part. Missing data may be assumed suitably.

Q. No.		**Question**	**Marks**	**RBT Level**	**CO**
		Part A			
1	a)	Draw a neat sketch of layout of hydroelectric power plant and **explain** the functions of each component. Also **define** different heads	5	L3	5
	b)	**Derive** the expression for force exerted by the jet on the inclined plate moving in the direction of the jet.	5	L2	
	c)	A Pelton wheel is to be designed for the following specifications: Shaft power = 11772 kW, Head = 380m, Speed = 750 rpm, overall efficiency = 86%, jet diameter is not to exceed one sixth of the wheel diameter. **Determine** i) the wheel diameter, ii) the number of jets required, iii) diameter of the jet. Take kv1= 0.985, ku1 = 0.45.	10	L3	
2	a)	**Explain** classification and efficiencies of turbines.	5	L2	5
	b)	**Derive** the expression for force exerted by the jet on the curved plate moving in the direction of the jet.	10	L2	
	c)	A Pelton wheel has a mean bucket speed of 10m/s with a jet of water flowing at the rate of 700l/s under a head of 30m. The buckets deflect the jet through an angle of 160°. **Calculate** the power given by water to the runner and the hydraulic efficiency of the turbine. Assume co-efficient of velocity as 0.98.	5	L3	
		Part B			
3	a)	A Francis turbine with an overall efficiency of 75% is required to produce 148.25 kW power. It is working under a head of 7.62m. The peripheral velocity = $0.26\sqrt{2gH}$ and the radial velocity of flow at inlet is $0.96\sqrt{2gH}$. The wheel runs at 150rpm and the hydraulic losses in the turbine are 22% of the available energy. Assuming radial discharge **determine** i) The guide blade angle ii) the wheel vane angle at inlet iii) diameter of the wheel at inlet iv) width of the wheel at inlet.	10	L3	6
4	a)	A Kaplan turbine working under a head of 20m develops 11772 kW shaft power. The outer diameter of the runner is 3.5m and hub diameter is 1.75m. The guide blade angle at the extreme edge of the runner is 35°. The hydraulic and overall efficiencies of the turbines are 88% and 84% respectively. If the velocity of wheel is zero at outlet, **Determine** i)Runner vane angles at inlet and outlet at the extreme edge of the runner. ii) Speed of the turbine.	10	L3	6

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
L1 : Remembering	L2 : Understanding	L3 : Applying
L4 : Analysing	L5 : Evaluating	L6 : Creating

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Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**CIE No.**	III
Date	3/8/21	**Max. Marks**	30

1) a)	Hydro electric power plant – layout Explain different heads	5
b)	Inclined plate moving in direction of jet, $F_x = \rho a (V-u)^2 \sin^2\theta$ $F_y = \rho a (V-u)^2 \sin\theta \cos\theta$	5
c)	~~d = 0.165m~~ dia of wheel = 0.989m No. of jets = 2 jets Dia of jet = 0.165m	10
2) a)	Classification Efficiencies of turbines	5
b)	Curved plate moving in direction of jet $F_x = \rho a (V-u)^2 \times u(1+\cos\theta)$	10
c)	$V_{w1} = V_1 = 23.77$ m/s $V_{w2} = 2.94$ m/s $W = 186970$ Nm/s Power = 186.97 kW $\eta_h = 94.54\%$	5
3)	$\alpha = 32° 37'$ $\theta = 37° 44.4'$ $D_1 = 0.4047$ m $B_1 = 0.177$ m	10

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4)	$\theta = 78^\circ 58'$ $\phi = 39^\circ 2'$ $N = 66.63$ rpm	10

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Assignment

Date	03	08	2021

Assignment No.	II	**Maximum Marks**	10
Course/Subject Title	Applied Hydraulics	**Course/Subject Code**	18CV43
Semester	IV A	**Scheme**	CBCS – 18
Course Co-ordinator	Ms. Supriya Xavier Lopes		

Note : Answer all the questions.

Q. No.	Question	Marks	RBT Level	CO
1	Obtain an expression for the work done by impeller of a centrifugal pump on water per second per unit weight of water.	3	L3	6
2	Explain with neat sketches, components and working of centrifugal pump.	3	L2	6
3	Derive the expression for minimum starting speed of a centrifugal pump.	4	L3.	6

Last date for submission	05	08	2021

RBT (Revised Bloom's Taxonomy) Levels : Cognitive Domain		
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L4 : Analysing	L5 : Evaluating	L6 : Creating

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